1. Framework

Marinus Dirk Stafleu

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1.1 Foundations research

Although there are many handbooks and textbooks of physics as well as numerous monographs and papers on special topics, until recently, there have been few books dealing with the structure of physics in a manner which goes beyond a mere commentary on its methods. Many of the texts, of course, are extremely important for the understanding of physics, and are fascinating because of new vistas explored or admirable because of clarity in expounding older views. However, there remains surprisingly few investigations into the basic structure and coherence of the physical sciences.

There is, perhaps, a historical explanation for this. The old philosophy of nature ("Naturphilosophie") assumed that the foundations of physics could be derived from "immediately evident truths" of an a priori, transcendent and necessary character. It was thought that these truths could be understood without the need of experimental verification. Especially in 19th-century central-European circles, attempts were made to build a structure of physics on such speculative foundations. Hegel is notorious in this respect. In time, however, it became clear that many of these "self-evident truths" were in fact false. In reaction, many late 19th- and 20th-century physicists rejected outright any a priori philosophical bias for their work - and willy-nilly became adherents of another philosophy: some variant of positivism (neo-positivism, Vienna school, analytical philosophy, instrumentalism, operationalism, conventionalism). Assuming that the *content* of science is "positive fact" which must be taken for granted, whereas the *structure* of science is determined by its *methods,* most positivist philosophers are interested only in the latter.[1] Hence for positivists, philosophy of

[1] On positivism, see P. Frank *Modern Science and its Philosophy* (1941), New York, 1961; L. Kolakowski *Positivist Philosophy* (1966) Harmondsworth, 1972; R. Von Mises *Positivism* (1939), New York, 1968; K. Popper 'Autobiography: replies to my critics' in Schilpp *The Philosophy of Karl Popper*, La Salle Ill, 1974 .

science is not a matter of ontology or epistemology, but rather a matter of methodology.

The study of the foundations of physics has traditionally been called "metaphysics", but, since the beginning of the 19th century, this term has become discredited because of its speculative implications. Currently, this kind of study is usually referred to as "foundations research". Bunge defines its goal as being twofold: "To perform a critical analysis of the existing theoretical foundations (of physics), and to reconstruct them in a more explicit and cogent way".[2] The critical analysis has three tasks:

"*(a)* To examine the philosophical presuppositions of physics;

(b) To discuss the status of key concepts, formulas, and procedures of physics;

(c) To shrink or even to eliminate vagueness, inconsistency, and other blemishes."[3]

Similarly, the task of reconstruction, according to Bunge, has three aspects:

"(a) To bring order to various fields of physics by axiomatizing their cores;

(b) To examine the various proposed axiomatic foundations;

(c) To discover the relations among the various physical theories."[4]

For Bunge, the most important tool of foundations research is axiomatization. In this context, " ... 'axiom' means *initial assumption* not self-evident pronouncement. There need be nothing intuitive and there is nothing final in an axiom ..."[5] Axiomatization of physical theories" ... does nothing but organize and complete what has been a more or less disorderly and incomplete body of knowledge: it exhibits the structure of the theory and makes its meaning more precise."[6]

However, since axiomatization is more an investigation of theories than of physics, it is unlikely that foundations research can be exhausted by formulating axioms. In the first place, axiomatization can only be applied to partial theories[7] such as classical mechanics, classical electromagnetism, thermodynamics, special and general relativity - to mention fields in which this type of foundations research has been carried out more or less successfully.[8] Moreover, as Whiteman observes, "... a

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[2] M. Bunge *Foundation of Physics*, Berlin, 1967, 1.
[3] Bunge *Foundation of Physics,* 1, 2.
[4] Bunge *Foundation of Physics,* 2.
[5] Bunge *Foundation of Physics,* 64; M. Bunge 'Physical axiomatics' *Rev Mod Phys* **39** (1967), 463-474
[6] Bunge *Foundation of Physics*, 68, 69.
[7] See Seagal in: Henkin, Suppes and Tarski (eds) *The Axiomatic Method*, Amsterdam, 1959, 341: ".. no axiom system is secure if it does not treat a closed system."
[8] M. Bunge (ed.) *Delaware Seminar in the Foundation of Physics* , Berlin, 1967; W. Noll *The Foundations of Mechanics and Thermodynamics*, Berlin, 1974.

conceptual system such as Euclidean geometry may be subjected to innumerable axiomatizations, all hazy in different ways."[9] In this book we shall not be primarily interested in partial theories, and we shall make use only occasionally of available axiomatizations. Our main focus will be with an ordering scheme of all aspects of the physical sciences - i.e., with the third of Bunge's "constructive tasks" of foundations research. It is very doubtful whether such an ordering scheme could be axiomatized in any sense, since any axiomatization would itself probably depend on such a scheme, whether explicitly recognized, or implicitly assumed. In our discussion, the partial theories neither are placed alongside one another, nor will they be deductively subsumed. They turn out to be interdependent and it is especially this mutual dependence which will be our subject matter.

A second reason for rejecting axiomatization as the main tool of foundations research is this: any modern axiomatization system familiar to me relies heavily on set theory, as well as on a formal logic making use of set-theoretic methods. This appears to betray a strong influence of Aristotelian philosophy of science, according to which science means the designation of classes and their mutual relations. This Aristotelian influence may be spurious; nevertheless, the approach relies heavily on logic, the laws of which are supposed to be true (if only "vacuously true") and a priori valid tools in foundations research. We shall consider set theory to be a mathematical theory, and insofar as logic makes use of it, logic has a retrocipatory character (cf. Sec. 2.5). Thus, sets and classes as mathematical entities should find a place within the general ordering scheme we are seeking. This implies that we cannot accept set theory and its dependent, axiomatization as the basis of our research into the foundations of physics, though both will play an important role in this book.[10]

From the above quotations it should be clear that Bunge's extreme emphasis on logical methods does not imply a purely deductive approach to physics, for his axioms must be found in existing physical theories. Still, he seems to adhere to the medieval idea that everything special is contained in the general. Cantore's "inductive-genetic" approach presents a somewhat different view: "First, the approach should be *inductive* ... the philosophical approach to science, to be

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[9] M. Whiteman *Philosophy of Space and Time*, London, 1967, 104, 105; cf. Bunge *Foundation of Physics*, 66; M. Jammer *Concepts of Mass* (1961), New York, 1964 Ch. 9, especially p. 120.
[10] Cp. H. Dooyeweerd *A New Critique of Theoretical Thought* (1955) vol. 2, 59. Gödel's theorem concerning the consistency and the completeness of axiomatized theories also shows some limitations of this method; cf. K. Gödel *On Formally Undecidable Propsitions of Principia Mathematica and Related Systems* (1931), Edinburgh, 1962-3 ; Bunge *Foundation of Physics*, 64.

successful, should concentrate on the detailed study of individual, fully developed theories. Secondly, the approach has to be *genetic*. Each scientific theory arises out of a slowly growing body of information. Hence the nature of the scientific endeavour and its achievements cannot be properly realized unless one follows the developments of individual theories as they gradually unfold and develop in time."[11] This points out my third objection to Bunge's position: the historical development of a theory must also be accounted for in foundations research.

Finally, I wish to direct a few comments to Bunge's first "critical task" of foundations research - viz., to examine the philosophical presuppositions of physics. First, it must be emphasized that there exists no unique set of philosophical presuppositions. Second, no examination of such presuppositions can itself be philosophically neutral. Bunge himself seems to be more clear about the philosophies which he rejects (positivism, operationalism) than he is about his own philosophical position (realistic objectivism, or critical realism[12]). This vagueness about one's own philosophy is not unusual among workers in foundations research. Since the beginning of this century it has become abundantly clear that mathematics and physics, and more specifically, investigations into their foundations, are not free from philosophical assumptions, which, in turn, depend on one's world and life view. Recognition of this has led to a more or less peaceful coexistence of different philosophical traditions in mathematics (logicism, formalism, and intuitionism)[13] and in physics ((neo-)positivism, operationalism, realism, conventionalism, materialism, and phenomenalism).[14] Since this book is not concerned primarily with philosophy, a complete criticism of any of these philosophical systems is impossible, but, at times, we shall have occasion to confront our view with the views of others.

The philosophical position from which the book is written is the so-called *Philosophy of the Cosmonomic Idea,* developed by Professors H. Dooyeweerd and D. H. Th. Vollenhoven at Amsterdam, during the second quarter of this century.[15] In contrast to philosophical fashion, this philosophy does not degenerate into a kind of

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[11] E. Cantore *Atomic Order*, Cambridge, MA, 1969, 5.
[12] Bunge *Foundation of Physics*, 44, 49,58,287; Bunge 'Physical axiomatics'.
[13] AA. Fraenkel, Y. Bar-Hillel *Foundation of Set Theory*, Amsterdam, 1958.
[14] These are contemporary philosophies. For an enumeration of eight mostly historical views on the relation of natural philosophy and science, see E. W. Beth *Natuurphilosophie*, Gorinchem, 1948, Ch.3; See also J. Losee *A Historical Introduction to the Philosophy of Science,* London, 1972.
[15] H. Dooyeweerd *NCTT* (vol 1-3) (1935-36) , Amsterdam, 1953, 1955, 1957: *In the Twilight of Western Thought* (ITTWT), Nutley, NJ; 1965, for an introduction to Dooyeweerd's philosophy, see L. Kalsbeek *Contours of a Christian Philosophy*, (1970), Toronto, 1975.

methodology. Growing out of the reformed biblical "ground motive" of creation, fall into sin, and redemption through Jesus Christ, it is a rather complicated attempt to account for the full complexity of created reality. Not only is this philosophy a systematic investigation into the structure of created reality and our knowledge thereof, but it also tries to account for the temporal development of created reality. For readers of this book it would be helpful to have prior knowledge of this philosophy. However, since only part of its elaborate system is needed for our analysis of the structure of physics, and since, insofar as we need it, we will elaborate the system in the course of this book, such prior knowledge is not strictly necessary. In this introductory chapter an outline of the general framework' within which our discussion takes place will be given. We do not wish to present this philosophy as an a priori truth; on the contrary, to a large extent, its applicability must be demonstrated by studies such as the one undertaken in this book. Hence we invite the reader to understand this introductory chapter as a provisional outline of a working hypothesis which is to be tested in the following chapters. In order to understand the structure of the physical sciences, we are in need of a philosophical system which makes possible *a systematic analysis of the foundations of physics*, including its history.

1.2 Three basic distinctions

Three central, recurring themes can be recognized in the history of scientific philosophy: the search for *truth,* the search for *order,* and the search for *structure.* The first is mainly a philosophical concern, and deals with the relation of laws and which is subjected to them, the status of law (the nominalism-realism controversy), the possibility of human knowledge, and the methodology of science. Its central problem is to account for the lawfulness of creation. The search for *order* and *structure* forms the core of science, and here one deals with questions such as: *Are there general modes of experience which provide an order for everything within the creation,* and if so, *which are these universal orders of relation? How can stable things exist, and how can they change?* The question of structure already surfaced in Greek philosophy and is still prominent in modern physics and biology, whereas the problem of order did not appear until post-Renaissance science. These three themes, though they cannot be treated separately, are irreducible to each other, and they lead to the introduction of three basic distinctions which form the skeleton of our philosophical theory.

(a) The distinction of law and subject (Sec. 1.3) is basic to all sciences, though it is not always explicitly recognized as such. Every science worth its name is concerned with laws. These laws are concerned either with more or less concrete things, events, signs, living beings, artifacts, social communities, etc., or with more or less abstract concepts, ideas, constructs, etc. These things which are subjected to law are commonly referred to as "objects", but, for reasons to be explained in Sec. 1.6, we shall refer to them as "subjects" - i.e., beings subjected to laws.[16] Though we will not deal with this problem extensively, we shall make a few comments about it, occasionally.

(b) The distinction of typicality and modality (Sec. 1.4). As mentioned above, we distinguish those "subjects" which are more or less concrete from those which are more or less abstract. This distinction is mirrored in the one between *typical,* special laws, which apply to a limited class of subjects, and *modal,* general laws, which hold for subjects of a more abstract character. Our first distinction (law and subject) is frequently identified with the distinction of universals and individuals. However, this identification is inadequate and too crude, since the distinction of typical and modal laws also implies a universal-individual duality. For the same reason, laws cannot be identified with classes or sets,[17] although special laws define classes. Modal laws, however, do not, and therefore cannot be found by generalization: they must be inferred by abstraction.

(c) The various modal aspects (Sec. 1.5). Various solutions to the problem of the general modes of experience have been presented. However, most of these attempt to solve the problem in terms of a *single* principle of explanation. This has led to a proliferation of "isms" in philosophy and science: arithmeticism (Pythagorean tradition), geometricism (Descartes' "more geometrico"), mechanism (Huygens, Leibniz, Maxwell), evolutionism, vitalism, behaviorism, logicism, intuitionism, historism, etc. In contrast to this trend, we shall attempt a solution in terms of *several* mutually irreducible modes of experience. Dooyeweerd was the first to recognize that

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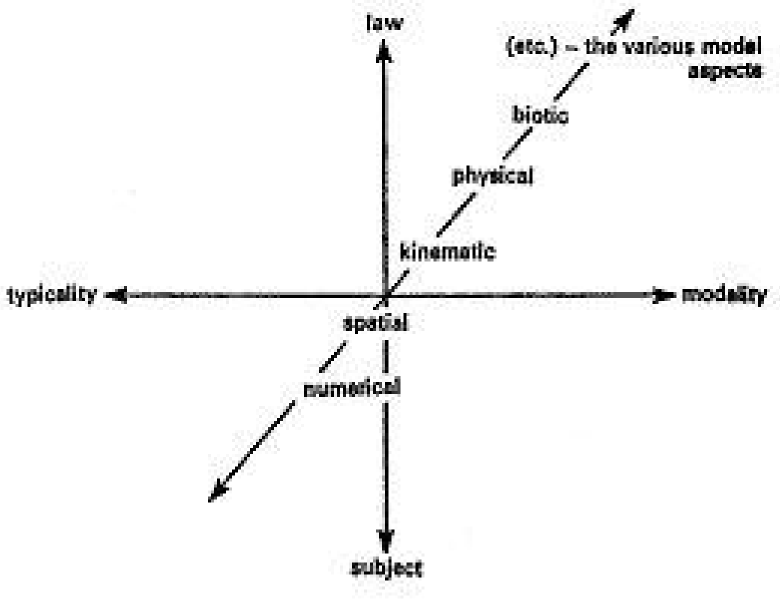
[16] We shall usually use the term "subject" as a noun. Instead of the adjective "subject" we use the somewhat uncommon "subjected". E.g. we write that a subject is *subjected* to law, not is *subject* to law. Cf. Dooyeweerd *NCTT* (vol 1), 108.

[17] Moreover, classes and sets have both a law side and a subject side, and cannot be identified with either one.

the modal laws can be grouped into several “law spheres” or “modal aspects”. Each modal aspect is of a general, universal character, but is irreducible to any other. We shall concern ourselves primarily with only four modal aspects which we designate as the numerical, the spatial, the kinematic, and the physical aspect.

The three basic distinctions which we have made above are neither dependent on each other nor reducible to each other. We may picture them as being mutually orthogonal, like the three axes in a Cartesian coordinate system. The three distinctions, though independent and irreducible, must be studied simultaneously, since they interpenetrate one another. It is not possible to discuss one of them without taking into account the other two. In the following sections I shall discuss these distinctions more extensively. During the discussion I shall point out several distinct *“aims of science”* which differ from one another to the extent that different viewpoints are possible within our systematics. I shall argue that each distinction implies a twofold direction (which I have tried to indicate by arrows in the diagram below). In the “horizontal plane” (orthogonal to the law-subject coordinate) these directions refer to the historical development of science (Sec. 1.7). This means that the systematics to be discussed below has a dynamic, not a static character.



1.3 Law and subject

The first basic distinction in our investigation of created reality is that of its law side and its subject side. In every philosophy, rightly called scientific, this distinction is explicitly or implicitly made; without it, science is impossible. This distinction is not merely a scientific, epistemological one, it is rooted in the creation itself. In fact, not only science, but all our life would be impossible without the awareness (mostly subconscious) of laws, distinct from subjects. In our lifetime we encounter things, animals, plants, men, human societies, organizations, and, above all, ourselves. All of these I refer to as "subjects", i.e., they are all subjected to some kind of law. Indeed, it is precisely because of these structural laws that we can distinguish the various subjects from one another, and explain and predict their behaviour. Without having some intuitive idea of structural laws which hold for plants, animals, etc., it would not be possible even to speak of them. We would be unable to perform even the simplest acts of life if we had no idea of, and confidence in, lawfulness.

There are no subjects without structural laws. Every subject is constituted by some law, and is related to other subjects by laws. The reverse is also the case. There are no laws without subjects (either possible or actual). The function of a law is to be valid for some or all subjects. These two sides of reality are correlative. As a result, we must avoid both rationalism, which overrates the law side of creation, and irrationalism, which over-emphasizes the subject side of reality. As *sides* of reality, both law and subject display the self-insufficiency of the creation. Via the law, subjects receive their *meaning* by pointing to their origin, the Divine creator of heaven and earth. Isolated from this relation, subjects lose their creational meaning. In the other direction, we believe that God maintains his creation via the laws. Lawlessness implies not only loss of meaning, but also self-destruction into nothingness.

Both the distinction of law and subject and their relation is an ontological matter. Since our pre-scientific knowledge of laws is primarily intuitive, the *primary aim of science* is to render these laws explicit, i.e. to *explicate* them. The laws are implicitly present in reality and, as such, are of a transcendent, a priori character. However, we have no a priori knowledge of the laws. Therefore our knowledge of laws, whether implicit or explicit, has both an empirical and a tentative character. It is important to distinguish laws in an ontological sense from our hypothetical law statements in scientific formulations. These statements are also frequently referred to as "laws".

Laws and subjects have an ontic nature, whereas theories, models and facts have an epistemic nature.[18]Thus, while electrons have always existed and the laws concerning them have always been valid, an electronic *theory* and the *fact* of the existence of electrons did not appear until 1896. Prior to that year the existence of an electron was not a fact. Theories, hypotheses, models and facts, though bound to the creation order, are human inventions. But laws and sub-human subjects exist independently of human knowledge.

We can discover laws, e.g., by induction, because they are related to subjects and we test the validity of our law statements by confirmation with facts. This state of affairs, however, does not mean that we can reduce laws to subjectivity. This was most clearly recognized by Hume, who argued that the "inductive assumption" concerning the possibility of finding laws by induction cannot be justified by experience. Hume insisted that there is no epistemic proof that laws concerning future events can be inferred from regularities observed in the past.[19] This discovery resulted, on the one hand, in a sceptical attitude concerning the very possibility of science and, on the other, in the conviction that laws have a merely epistemic status. We share neither of these views. For us, the possibility of discovering laws is based on faith in the lawfulness of reality and in a God who faithfully maintains his laws. Admittedly, the lawfulness of reality cannot be proved. It is an *a priori* of all human experience, including scientific experience.[20] According to the Philosophy of the Cosmonomic Idea, different philosophical systems can be characterized according to

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[18] M. Bunge *Causality* (1959), Cleveland, 1963, 245ff; M. Bunge *Foundations of Physics*, Berlin, 1967, 44; Bunge *Causality*, 249 defines laws as "... the immanent patterns of being and becoming ..." law statements as "... the conceptual reconstructions ..." of laws. The relation of law and subjects, and the status of theories, models, facts, induction, deduction, and reduction arc objects for epistemological research. See e.g. C. G. Hempel *Fundamental Concept Formation in Empirical Science,* Chicago, 1969; *Aspects of Scientific Explanation,* New York, 1965; *Philosophy of Natural Science,* Englewood Cliffs, 1966; E. Nagel *Principles of Probability Theory*, Chicago, 1969; K. Popper *The Logic of Scientific Discovery* (*LSD*), New York, 1968, *Conjectures and refutations* (*C&R*), (1962), New York, 1969; W. Stegmüller *Probleme und Resultante der Wissenschaftstheorie und Analytischen Philosophie Band II: Theorie und Erfahung*, Berlin, 1970.

[19] D. Hume *An Enquiry Concerning Human Understanding* (1748), *A Treatise of Human Nature* (1739), La Salle, Ill, 1971; R. B. Braithwaite *Scientific Explanation* (1953), Cambridge, 1968, Ch. 9; E. E. Harris *Hypnosis and Perception,* London, 1965 39, 40; L. Kolakowski *Positivist Philosophy* (1966) 42-59; J. Losee *A Historical Introduction to the Philosophy of science,* London, 1972, 101-106; K. Popper *Objective Knowledge* (*OK*) (1972), Oxford, 1974, 1-31, 55-105; B. Russell *History of Western Philosophy* (1946), London, 1967, 634-647. Dooyeweerd *NCTT* (vol 1), 275ff observes that Hume's scepticism has a methodological significance, intended to reinforce his psychological ideal of science.

[20] Even the existence of subjects outside ourselves cannot be proved, as was shown by solipsism; cf. B. Russell *The Analysis of Matter* (1927), London, 1959, 27ff.

their respective views on the status of law.[21]Thus the *name* of this philosophy does not lay a claim on the "cosmonomic idea". Rather it pleads for the recognition that any philosophical system must account for the lawfulness of reality. Such an account does not have a scientific starting point, but a religious starting point, which has scientific consequences.

The positivist view that the truth of law statements can be established by verification of their factual consequences has been criticized by Popper.[22] However, Popper's "falsifiability criterion", though a correction to the positivist view, is only sufficient to "demarcate" scientific from non-scientific law statements. Regardless of how much evidence may "corroborate" a natural law statement, acceptance of the statement as law is always a matter of faith. A law statement is ultimately *believed* to be true, because of convincing evidence supporting it. This belief does not *prove* that the law statement is true, for such proof does not exist. This belief is neither individual nor irrational; it is *communal,* i.e., the community of scientists decides on the faithfulness of the empirical evidence and the acceptability of physical theories.[23] To perform this task the scientific community organizes societies, journals, etc., in which the evidence is judged and debated, according to unwritten codes. Even then, the truth of any law statement cannot be absolutely proved or disproved. Indeed, in many cases, scientific research is initiated because someone (on quite rational grounds) does not believe the accepted views on some particular subject.

Ultimately, an acceptance of the truth of law statements and empirical evidence is based on belief, both in the reliability of our colleagues, and in the lawfulness of the creation. Hence there is room for the rejection of formerly held law statements, and the critical reconsideration of older evidence in the light of new evidence or insights. This same state of affairs applies to our consideration of subjects. Because of the correlation of law and subject, our knowledge of facts is always theory-laden. Thus, at present, it seems quite certain that electrons and stars are real existing entities,

[21] See Dooyeweerd *NCTT* (vol 1), 93ff. For a discussion of the status of Newton's second law of motion (which could serve as an illustration of this assertion), cf. N. R. Hanson *Patterns of Discovery*, Cambridge, 1972, Ch.5.

[22] K. Popper *LSD*, Ch. 1.

[23] The influence of communal belief on accepted theories has been emphasized by T. S. Kuhn *The Structure of Scientific Revolutions* (*TSSR*) (1962),Chicago, 1971, 'Logic of discovery of psychology of research', 'Reflections on my critics' in Lakatos and Musgrave *Criticism and the Growth of knowledge*, (1970), London, 1974; see also Bunge *Foundation of Physics*, 70; Harris *Hypnosis and Perception* ; J. M. Ziman *Public Knowledge,* (1968), Cambridge, 1974; *The Force of Knowledge*, Cambridge, 1976.

whereas we are far less sure about the existence of quarks and quasars. In these cases, too, the degree of certainty depends upon the availability of independent, reliable evidence. In our opinion, both laws and subjects are "discovered", implying an active role for the scientific explorer. How theories are found or invented is not well understood. The scientist's phantasy and genius itself is subjected to historical and psychological research, and certainly cannot be reduced to simple logical rules for deduction and induction.[24]

Though the number of laws may be infinite, they are not all independent, and it is often possible to deduce one law statement from others. In this case we say that the former is reduced to the latter. The reduction of laws and, conversely, the deduction of new laws and their consequences for subjects is the *second aim of science.* Axiomatization can be a very helpful tool in investigating the possibility of such reduction schemes. Attempts to reduce all laws to a single principle have been made in every epoch of philosophy, beginning with Thales' "Everything is made of water".[25] In classical physics an attempt was made to explain all physical phenomena from the motion of unchangeable pieces of matter. We share none of these reductionist views - in fact, we shall assume that the mutual irreducibility of the various modal aspects precludes its possibility.

1.4 *Typicality and modality*

In addition to the distinction of law and subject, it is very fruitful to introduce a second basic distinction, that of typicality and modality. Hereby, we distinguish laws which are valid for a limited class of subjects (typical laws) from those which are valid for all kinds of subjects (modal laws). Typical laws, in principle, delineate the class of subjects to which they apply, describing their structures and typical properties. Examples of such laws are the Coulomb law (applicable only to charged subjects), the Pauli principle (applicable only to fermions), etc. Often the law describing the structure of a particular subject (e.g., the copper atom) can be reduced

[24] T. S. Kuhn *TSSR*, Ch. 2; P. K. Feyerabend *Against Method* London, 1975; I. Lakatos 'Falsification and the methodology of scientific research programmes', in *The Methodology of Scientific Research Programmes*, Cambridge, 1978; G. Holton *Thematic Origins of Scientific Thought*, Cambridge, MA, 1973, Ch. 10; G. Holton *The Scientific Imagination*, Cambridge, 1978, Ch. 3; M. A. Finocchiaro *History of Science as Explanation*, Detroit, 1973.
[25] Russell *History of Western Philosophy*, 44, 61.

to some more general typical laws (e.g., the electromagnetic laws in quantum physics). On the other hand, modal laws are those which have a universal validity. For example, the law of gravitation applies to all physical subjects, regardless of their typical structure. We call them *modal* laws because, rather than circumscribing a certain class of subjects, they describe a *mode* of being, relatedness, experience, or explanation.

This distinction is also relevant to the way in which different laws are discovered and formulated. Whereas typical laws can usually be found by induction and generalization of empirical facts or lower-level law statements, modal laws are found by abstraction. Euclidean geometry, Galileo's discovery of the laws of motion and the subsequent development of classical mechanics, and thermodynamic laws are all examples of laws found by abstraction. This state of affairs is reflected in the use of the term "rational mechanics", in distinction from experimental physics.

At first sight the distinction between typicality and modality appears to apply only to laws. Indeed, all concretely existing things, events, organisms, etc., have some typical structure. However, even as modal laws are found by abstraction, *modal subjects*, which are abstracted from any typical and individual properties, are also found to exist. The modal subjects (so-called because they are exclusively subjected to modal laws) are indispensable in science for the ordering of our experience. Numbers, spatial figures, inertial systems, wave packets, and isolated systems are all examples of modal subjects. They do not 'exist' in any *concrete* sense, since they lack any individuality and typicality. Nevertheless, in the sense of belonging to created reality, these subjects are perfectly real – they are abstracted form concrete, individually existing things, events etc. We must disentangle typical laws in order to discover modal laws. This process could not be carried out without the use of abstract modal subjects. We may call abstraction the *third aim of science*, which includes the formulation of modal, universal laws, as well as the modal analysis of concrete reality on both the law side and the subject side.[26]

The distinction of typicality and modality is, however, not merely an epistemological one, for though there is a plurality of laws and subjects, there is only one reality. This means that even though subjects may have· widely differing typical

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[26] We relate "abstraction" to the distinction of modality and typicality. As we shall see, one may also speak of abstraction in another sense if one studies a modal aspect without considering the succeeding modal aspects. In experimental physics one *isolates* a system (and in theories one isolates a problem) - in order to keep it under control - by keeping some influences constant while changing one or more others.

structures, they must be related in a general way. It is these general (thus modal) subject-subject relations which come to the fore when we study modal laws (cf. Sec. 1.5). For instance, two physical subjects, regardless of their typical, individual structures, are always related, since they must have a certain spatial distance and a certain relative velocity. But in order to investigate these general relationships, we must deprive the subjects of their typicality - i.e., modal laws have correspondent modal subjects.

The distinction of typicality and modality is not of great importance in mathematics because, as we shall see, this science is concerned primarily with purely modal laws. As a result, many philosophers and mathematicians have assumed that mathematics is just a branch of logic. However, physics is concerned not only with modal laws, but also with typical laws regarding the typical structure of atoms, crystals, stars, etc. Therefore, in the physical sciences, more so than in mathematics, the distinction of general, modal laws and specific, typical. laws becomes important. This does not mean that mathematics is less empirical than physics. It would be an oversimplification to state that mathematics, as a "formal science", is concerned with modal, a-typical laws, whereas physics, as an "empirical science", deals with typical laws and, therefore, with concrete reality.[27]

A *fourth aim of science* is the reconstruction or synthesis of typical laws. After finding some general characteristics of a certain structure (e.g., the number of protons and neutrons in a helium nucleus) by modal analysis, an effort to find the typical law for this system may be made. Since modal laws are too universal to form any typical structure, the starting point for the reconstruction cannot be taken solely in the modal laws themselves. As it happens, in physics, in addition to purely modal gravitational interaction one must also consider electromagnetic interaction and two types of nuclear interaction. Despite many efforts toward the development of a "unified field theory", these fundamental interactions cannot be reduced to one another. With the help of modal laws and these typical interactions of a sufficiently general character, an enormous number of typical structures may be formed: nuclei, atoms, molecules, crystals, particles, quasi-particles, etc. Investigations of these structures reveal both sides of the modality-typicality distinction: abstraction and reconstruction, analysis

[27] Cp. Bunge *Foundation of Physics*, 28. It is also useless to consider mathematics as "analytical" and physics as "synthetic" (cp. J. M. Jauch *Foundations of Quantum Mechanics*, Reading MA, 1968, 70).

and synthesis. Without the existence of the irreducible fundamental typical interactions, typical laws could be subsumed under modal laws. Because of their irreducibility, the distinction of typicality and modality must be recognised as being "orthogonal" to the distinction between law and subject.

Our distinction of typicality and modality appears in several other philosophical systems in one form or another. Campbell distinguishes typical laws from other laws. He calls typical laws "…laws of the kind which assert the properties of a kind of system ... The 'classificatory' sciences differ from other sciences in that they confine themselves to laws of this type…"[28] Margenau[29] speaks of the "immediately given" from which a scientist passes to "orderly knowledge" by the formation of "constructs". Between the former and the latter there are "rules of correspondence" and there is a "circuit of empirical confirmation". Bunge[30] states "Every physical idea is expressed in some language and has a logical structure and a context of meaning.[31] The language has a (modal) syntax or grammar and, via a semantics, is connected with reality. From our point of view, we may recognize this because the logical and lingual modal aspects have a universal character, but we avoid the pitfall of absolutizing them. There are other universal and irreducible modal aspects as well. While recognizing that both logic and language are indispensable for the human act of scientific abstraction and reasoning, we shall not concern ourselves further with these epistemological problems.

1.5 The modal aspects

The theory of the modal aspects is one of the most important chapters in the Philosophy of the Cosmonomic Idea developed by Prof. H. Dooyeweerd. He says:

" ... our theoretical thought is bound to the temporal horizon of human experience and moves within this horizon. Within the temporal order, this experience displays a great diversity of fundamental modal aspects, or modalities which in the first place are aspects of time itself. These aspects do not, as such, refer to a concrete *what,* i.e., to concrete things or events, but only to the *how,* i.e., the particular and fundamental

[28] N. Campbell *What is Science?* (1921), New York, 1952, S6, S7.
[29] H. Margenau, *The Nature of Physical Reality*, New York, 1950, Ch. 3-6.
[30] Bunge *Foundation of Physics*, Ch. 1.
[31] Bunge *Foundation of Physics* 9; sec also M. Jammer *The Philosophy of Quantum Mechanics*, New York, 1974, 10ff

mode, or manner, in which we experience them. Therefore we speak of the modal aspects of this experience to underline that they are only the fundamental *modes* of the latter. They should not be identified with the concrete phenomena of empirical reality, which function, in principle, in all of these aspects. Which, then, are these fundamental modes of our experience? I shall enumerate them briefly.

"Our temporal empirical horizon has a numerical aspect, a spatial aspect, an aspect of extensive movement, an aspect of energy in which we experience the physico-chemical relations of empirical reality, a biotic aspect, or that of organic life, an aspect of feeling and sensation, a logical aspect, i.e., the analytical manner of distinction in our temporal experience which lies at the foundation of all our concepts and logical judgments. Then there is a historical aspect in which we experience the cultural manner of development of our societal life. This is followed by the aspect of symbolical signification, lying at the foundation of all empirical linguistic phenomena. Furthermore there is the aspect of social intercourse, with its rules of courtesy, politeness, good breeding, fashion, and so forth. This experiential mode is followed by the economic, aesthetic, juridical and moral aspects, and, finally, by the aspect of faith or belief."[32]

Dooyeweerd argues that the several modal aspects are *mutually irreducible*. Because of the genetic character of scientific knowledge the designation of the various modal aspects must always be of a tentative and hypothetical character. Dooyeweerd himself did not distinguish the kinematic from the physical modal aspect until 1953.[33] The distinction of two mutually irreducible modal aspects is based on an analysis of our contemporary knowledge. We shall report on such an analysis for the first four modal aspects, which, for the sake of brevity, we designate as the numerical, the spatial, the kinematic, and the physical modalities.

In science, the different modes of experience can be different *modes of explanation* as well. As a result, we are provided with a possible distinction of the special sciences on an ontological basis, at least insofar as a special science can be characterized by one of the irreducible modes of explanation. In principle, each modal aspect has a corresponding special science: arithmetic or algebra with the numerical aspect, geometry with the spatial aspect, kinematics with the kinematic aspect, physics

[32] Dooyeweerd ITTWT, 6, 7; see also Dooyeweerd *NCTT* (vol 1), 3; on the criterion of a modal aspect, see Dooyeweerd *NCTT* (vol 2), Ch. 1.
[33] Dooyeweerd *NCTT* (vol 2) 98; Dooyeweerd's view on these two modal aspects is not shared by all adherents of his philosophy. There is also some disagreement on several other modal aspects.

(including chemistry and astronomy) with the physical aspect, biology with the biotic aspect, etc.[34] This classification is not exhaustive, however, since some sciences (geology, for example), study certain structures from the viewpoint of several modal aspects, no single one of which takes a leading role.

Temporal reality is a multiply-connected pattern of relations. Although many of these relations have a typical structure, it is only possible to understand the unity, i.e., the mutual relatedness of all subjects in the creation, if at least some of these relations are of a modal, universal character. All concrete existing things, events, etc., have mutual numerical, spatial, kinematic, and physical relations, and it is these mutual relations that make it possible for us to become aware of and understand these subjects. We are, therefore, entitled to speak of the modal aspects as *universal modes of temporal relations.*[35]

Within this modal relatedness we may distinguish a law side and a subject side. On the law side, in each modal aspect, we find a distinct modal order, which is correlated with a modal subject-subject relation on the subject side. In the *numerical* aspect the modal order is the serial order of smaller and larger, or earlier and later. This modal order originally correlates with the numerical difference or ratio of two numbers, as modal, numerical subject-subject relations. The modal order in the *spatial* modal aspect is that of simultaneous coexistence, which is correlated with the relative spatial position of two subjects on the subject side. In the *kinematic* modal aspect the modal order of time flow is correlated with subjective relative motion, and in the *physical* aspect the modal order appears as irreversibility, which is correlated with the physical interaction of two or more subjects on the subject side.

As it turns out, the modal order in every modal aspect refers to our common understanding of *time,* since earlier or later, simultaneity, time-flow, and irreversibility are all acknowledged temporal relations. At first sight, the same cannot be said of the modal subject-subject relations such as relative position and interaction. However, we shall see that on the subject side, the opened-up numerical subject-subject relations (anticipating other subject-subject relations) most closely

[34] The prevailing positivist view reverses the creational order by stating that the sciences must be classified according to their methods (cf. Margenau *The Nature of Physical Reality,* 46).
[35] The theory of time discussed in this book differs slightly from Dooyeweerd's; cp. H. Dooyeweerd 'Het tijdsprobleem in de wijsbegeerte der wetside' *Philosophia Reformata* **5** (1940), 162-182, 193-234; *NCTT* (vol 1) 22-34.

approximate what we usually refer to as “time”. This is most clearly shown by an analysis of the historical development of time measurement, at least insofar as such a development can be reconstructed. Initially, time measurement was simply done by *counting* (days, months. years. etc.). Later, time was measured by the relative *position* of the sun or the stars in the sky, with or without the help of instruments such as the sundial. In still more advanced cultures, time was measured by utilizing the regular *motion* of more or less complicated clockworks. Finally, in most recent developments time is measured via *irreversible* processes, for example, in atomic clocks.

In a scientific context, however, it is inadequate to work with either a simple common notion of time, or a merely objective representation of subjective relations. All modal subject-subject relations as well as the modal orders to which they are subjected must be recognized as being “temporal”. *Time relates all subjects to each other under a universal law of order.* The question as to whether time is relational or absolute in some sense has long been debated and ‘still has not been settled.[36] We reject any notion of absolute time. “Absolute time” infers a unique universal reference system. We shall show that our theory of modal time requires the existence of several classes of reference systems - none of them unique, all of them universal - which allow an objective description of our world.

Although the modal aspects are mutually irreducible, they are neither unconnected nor independent. The modal aspects display a serial order. As a result we can speak of “earlier” and “later” modal aspects in the sense that a later modal aspect presupposes the earlier ones. For example, the spatial modal aspect presupposes the numerical aspect. If this were not so, it would not be possible to speak of *three-dimensional* space, the *four* sides of a square, or any other numerical attribute of spatial functioning. In a similar way, the spatial aspect is presupposed by the kinematic modal aspect, which in its turn, is presupposed by the physical aspect. Similarly, the biotic aspect presupposes the physical aspect, and so forth. Terminologically, we say that the later aspects *refer back to,* or *retrocipote on* the earlier ones. Thus each modal aspect, except for the numerical (first) aspect, contains *retrocipations.* Indeed, the meaning of any modal aspect cannot be fully grasped without an insight into its retrocipations. Conversely, we refer to the counterparts of

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[36] For an anthology on the problem of time, cf. M. Gale (ed.) *The Philosophy of Time.* Garden City, 1967 ; J. Zeman (ed.) *Time in Science and Philosophy,* Amsterdam, 1971 .

retrocipations as *anticipations*. Not only does each modal aspect (except the first) retrocipate on the earlier aspects, but each earlier aspect (except the last) *anticipates* the later ones. In our discussion we shall be concerned only with the retrocipations and anticipations between the first four modal aspects. We shall observe that the anticipation of aspect A on aspect B is closely related to the retrocipation of B on A. These anticipations and retrocipations are also referred to as *analogies*. In keeping with our distinction between the law side and the subject side of reality, we shall find these analogies on both the law and subject side of creation. The analogies are, perhaps, even more important for scientific investigations than the "bare" modal aspects themselves. Thus. the view that the modal aspects form a sort of "layer" structure in reality, with each layer built upon the earlier ones, is prohibited. Rather than being well separated departments of reality, the modal aspects are intertwined, mutually irreducible, indispensable aspects of reality.[37] The designation and distinction of modal aspects and the exploration of their retrocipations and anticipations may be called the *fifth aim of science*.

The distinction of the modal aspects is relevant, not only to modal laws and modal subject-subject relations, but also to *typical* relationships. A typical structural law may be viewed as a typical conglomerate of relevant modal and· (general) typical laws. Such a typical structural law has two limiting modal aspects, which we designate as the *founding* aspect, and the *leading*. or *qualifying* aspect. For example, atoms, stones, and stars are *qualified* by the physical modal aspect (we call them "physical things"), whereas plants are qualified by the biotic aspect. On the other hand, the structure of an atom is *founded* in the spatial modal aspect, since it consists of a nucleus surrounded by an appropriate number of electrons. In contrast, particles are founded in the numerical modal aspect, since they are characterized only by typical magnitudes. This intricate state of affairs, which we shall discuss in greater detail in Chapter 10, is further complicated by the fact that, within an atom, the nucleus, though itself spatially founded, functions as a particle. Such a relationship is referred to as "*enkapsis*"*:* the structure of the nucleus is "enkaptically bound" within the structure of the atom. In the same way, atoms are "enkaptically bound" within the

[37] On the analogies. see Dooyeweerd *NCTT* (vol 2), Ch. 2.

structure of a molecule, and molecules within the structure of a living cell.[38]

Hence we state the modal aspects to be mutually irreducible but connected modes of *experience,* modes of *explanation,* modes of *order,* and modes of *temporal relations.* It should not be surprising to find that modes of experience and explanation are identified with modes of order and relation. In a broad sense, explanation means to order pieces of experience by relating them to other pieces of experience under a law. The modal aspects should not be understood in a Kantian sense as self-evident a priori modes of thought laid bare by a metaphysics independent of empirical science. On the contrary, our arguments for the designation of the modal aspects will be found in science (understood as the investigation of the creation), not in metaphysical speculation, based on a supposed autonomy of human thought.

1.6 Subjects and objects

We have now covered enough ground to justify our use of the word “subjects” to designate things which, perhaps, are more commonly referred to as “objects”.[39] In fact, we prefer the linguistic use of these words, which is more original than the modern scientific and philosophical use of them.

We turn our attention to the following question: Is it possible to speak of modal, universal, biotic laws which are valid for all kinds of subjects, regardless of their typical structure? Initially, it would seem that a stone, for example, is not subject to biotic laws. In order to answer this question adequately, however, it is necessary to distinguish between “subjects” and “objects”. Subjects are those things which are actively or directly subjected to a certain law, whereas objects, in contrast, are related to the law only passively or mediately. This implies that objects receive their creational meaning from the subject to which they are related by a subject-object relation. Thus a stone cannot be a biotic *subject.* Only organisms can be subjects to biotic laws. But atoms and molecules, rocks and sticks, may function as biotic *objects* within the sphere of some biotic law. For example, a bird’s nest, as a subject, is subjected to only mathematical and physical laws (it has mathematical and physical “subject functions”). As a bird’s nest, however, it can be understood adequately only as a biotic “object”; the nest has an objective biotic qualifying aspect. The bird’s nest

[38] Dooyeweerd *NCTT* (vol 3), 627 ff
[39] Dooyeweerd *NCTT* (vol 2), Ch. 5.

receives its true objective biotic meaning through its relation to a bird, which is a biotic subject.[40]

The distinction of subject and object is not limited to typical structures of reality. Subjects and objects also appear on the modal side of reality. A spatial point, having no extension, functions as a spatial modal object. Similarly, the path of a moving subject is a kinematic modal object since the path itself is motionless; and the state of a physical subject is a physical modal object since states do not interact. An object in some modal aspect is always a subject in another aspect. Therefore, the subject-object relation within some modal aspect is connected with the retrocipations *of* that aspect, and with the anticipations *on* it.

It is also possible to speak of subjects and objects in an epistemological context. In this case, however, only man can be a subject, since things, events, plants, and animals always remain objects of scientific or common thought. The latter can only function as subjects in an ontological context. As we have already noted, epistemology has taken priority over ontology in the dominant western philosophies. Since the Renaissance the ground motive of western thought has been the relation of freedom and nature – i.e., the relation of human thought and activity, and its natural object.[41] In developments of the past four or five centuries, the natural subjects have become increasingly objectified. Whereas they retained an independent existence, determined by their spatial extension or mechanical inter-action in the philosophy of Descartes, Newton and Leibniz, natural subjects were denatured, in principle, to unknown "Dinge an sich" in Kant's thought. In modern positivistic and phenomenalistic thought they became mere appearances. Occasionally existentialistic circles have tried to restore nature in a purely individual relation of man and his environment. Parallelling this development, natural laws were reduced to mere epistemic ordering principles, whether a priori and unavoidable (Kant), merely economic (Mach), or conventional (Poincare).

These developments are reflected in our modern terminology. Today we generally speak of natural objects, even when we discuss their subjectivity to natural law. The modern view is strongly oriented towards a completely functionalistic view of reality

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[40] Dooyeweerd *NCTT* (vol 1), 42-43.
[41] Dooyeweerd *NCTT* (vol 1); ITTWT; for the subject-object relation in humanist philosophies cf. Dooyeweerd *NCTT* (vol 2), 367 ff

- i.e., the modal aspects considered as universal modes of thought are the dominant principles of explanation. In this respect, post-Renaissance philosophy differs sharply from Greek and medieval philosophies, which were usually dominated by a typicalistic view, most clearly exemplified in Aristotle's form-matter scheme.[42]

For Christian philosophy there is no need to absolutize any modal aspect, or any typical structure or relationship. At its foundation lies the acknowledgement that the creation is not independent of its Creator. On the one hand, there is no "substance" which exists independently of law, and, on the other hand, all natural subjects exist as creatures (being and becoming) under law. Because they are all subjected to laws, all subjects point to the Lawgiver: "Meaning is the mode of being of all that is created."[43] This implies that natural subjects acquire their *full* meaning only if, in addition to tbeir subject functions, all of their object functions are also opened up in their relation to man. In this relation natural subjects receive their full religious meaning since, in his relation to God, man is the religious centre of the creation.

The distinction of subject and object enables us to achieve a clear insight into the terms "objectification" and "objectivity". In humanistic thought everything which relates to sub-human subjects is referred to as "objective". As a result, the demand for an "objective science" has acquired an entirely confused meaning. It is sometimes understood as being "intersubjective" or "public". In this case one distinguishes between individual (subjective) experience and public (objective) experience.[44] In other contexts objectivity is con- fused with universal validity or law conformity. In the Philosophy of the Cosmonomic Idea, the meaning of the word objective is clear: *objectivity means a representation of modal and typical states of affairs referring back to earlier modal aspects.* Objectification is made possible by the existence of retrocipations on these earlier aspects, and the opening up of the latter's anticipations.

[42] Dooyeweerd *NCTT* (vol 2), 12; S. L. Jaki *The Relevance of Physics*, Ch. 1.
[43] Dooyeweerd *NCTT* (vol 1), 4.
[44] Cf. e.g. Popper *LSD*, 411f, but also I. Kant *Kritik der reinen Vernunft* (1781), Frankfurt, 1974, 820, I. Kant *Kritik* (1787), 848; for Popper, objectivity of scientific statements lies in the fact that they can be intersubjectively tested, which implies that the described phenomena should be reproducible. See also H. Margenau and J. L. Park, 'Objectivity in quantum mechanics' in M. Bunge (ed.) *Delaware Seminar in the Foundation of Physics*, Berlin, 1967,who enumerate the following "meanings of objectivity": ontological existence ("the objective reality behind perceptible things"); intersubjectivity; invariance of aspect ("objectivity must be assigned to those properties which are, or can be made, invariant"); scientific verifiability ("Constructs which satisfy the metaphysical requirements as well as the stringent rules of empirical confirmation are called verifacts, and verifacts are the carriers of objectivity in the domain of theory"). The "metaphysical requirements", e.g. Occam's razor, economy of thought, logical fertility, simplicity, are discussed in Margenau *The Nature of Physical Reality*, Ch 5.

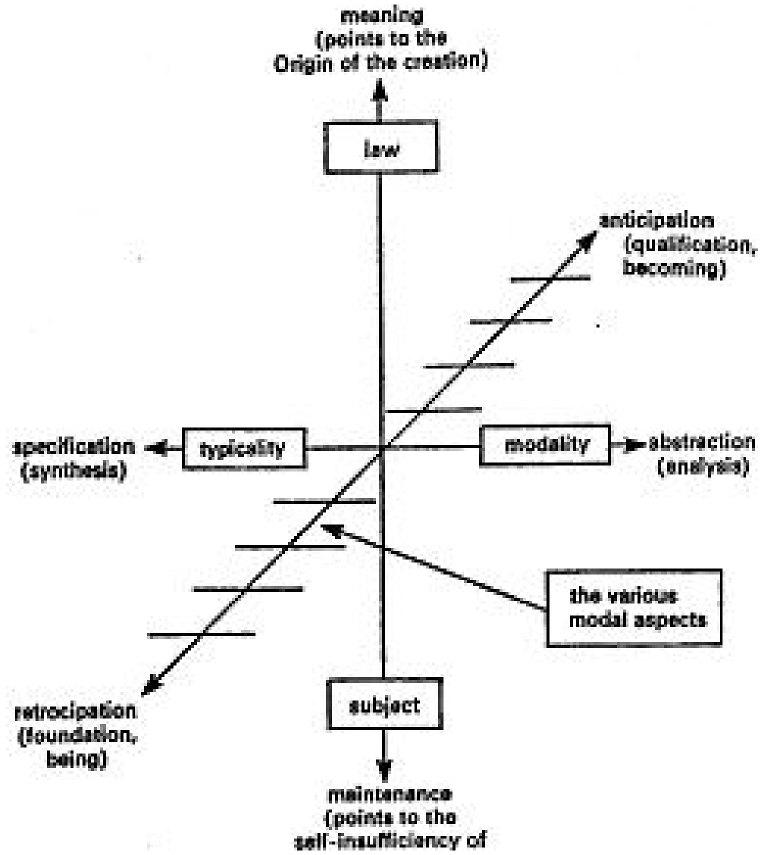
The problem of objectification, which may be termed the *sixth aim of science*, shall occupy much of our attention. Spatial points, which refer back to the numerical modal aspect, enable us to find an objective numerical representation of spatial magnitudes and relative positions (cf. Chapter 2). The path of motion, referring back to the spatial modal aspect, provides us with an objective representation of the motion of a kinematic subject (cf. Chapter 4). Similarly, the state of a physical system allows us to objectify the system's interaction with other systems (cf. Chapter 5).

For physics, objectification means a representation of physical states of affairs in mathematical terms. It is frequently said that mathematics is the language of physics,[45] as if it were a merely linguistic matter. This view is erroneous and confusing. The real state of affairs is more complicated. The modal aspects, which precede the physical aspect and form the subject matter of mathematics, are universal aspects of the full creation, including physically qualified things and events. It is impossible to account for physical functioning without including the earlier aspects in one's analysis.

1.7 The opening-process

The three basic distinctions discussed so far define three mutually orthogonal two-fold directions. This means that our theory is intended not only to give a systematic description of contemporary knowledge of reality, but also, as an historiography, to account for the dynamic development of science. In the figure below (compare page 7) the vertex may in fact be placed in each modal aspect, except that there is no retrocipation in the first, and no anticipation in the last modal aspect.

[45] cf. Galileo, in: S. Drake (ed.) *Discoveries and Opinions of Galileo*, Garden City, NY, 1957, 237, 238.



When anyone of the modal aspects is recognized as a basic principle of explanation, the development of its anticipations and retrocipations is sought by means of abstraction and specification, or analysis and synthesis. This procedure is referred to as the "*opening process*",[46] and it occurs in the "horizontal plane" (see figure). perpendicular to the vertical co-ordinate which has primarily religious meaning. We shall consider the opening-process in some detail.

Quite recently, several scholars in the history of science have pointed toward this opening-process. Specifically, they reject the view that " ... scientists are men who, successfully or not, have striven to contribute one or another element to that particular constellation (of facts, theories, and methods collected in current texts) ... ", such that" ... scientific development becomes the piecemeal process by which these items have been added, singly and in combination, to the ever growing stockpile that

[46] We use this idea in a somewhat wider sense than Dooyeweerd does: cp.
Dooyeweerd *NCTT* (vol 1), 29, (vol 2), 181ft; and M. D. Stafleu 'The isolation of a field of science' *Philosophia reformata* **44**, 1979, 1-15; 'The mathematical and the technical opening up of a field of science' *Phil. Ref.* **43**, 1978, 18-3; 'The opening up of a field of science by abstraction and synthesis' *Phil. Ref.* **45**, 1980, 47-76. In which our views of the opening-process are applied to the 18th- and 19th-century history of electricity and magnetism.

constitutes scientific technique and knowledge".[47]

Kuhn, in his famous book, *The Structure of Scientific Revolutions*, introduced the distinction between "normal science", which is guided by some time-honoured "paradigm", and "scientific revolutions", during which one paradigm is replaced by a new one.[48] Prior to the introduction and acceptance of any paradigm, " ... the early developmental stages of most sciences have been characterized by continual competition between a number of distinct views of nature ... What differentiated these various schools was ... their incommensurable ways of seeing the world and of practicing science, in it …"[49] After a communis opinio is established " ... on the assumption that the scientific community knows what the world is like ..."[50] normal science proceeds as " ... a strenuous and devoted attempt to force nature into the conceptual boxes supplied by professional education".[51] Eventually, in the course of normal science, anomalies, which cannot be understood within the existing framework, appear and " ... then begin the extraordinary investigations that lead the profession at last to a new set of commitments, a new basis for the practice of science."[52]

Holton's *Thematic Origins of Science* also points to the difficulty with which new ideas are accepted. Referring to Einstein's Principle of Relativity, he observes: "... it is precisely such non-verifiable and non-falsifiable (and not even quite arbitrary) thematic hypotheses which are most difficult to advance or to accept. It is they which are at the heart of major changes or disputes, and whose growth, reign and decay are much neglected indicators of the most significant developments in the history of science."[53] Holton's themes are somewhat more general and less specific, and therefore more persistent, than Kuhn's paradigms. I wonder whether Kuhn would call "paradigmatic" the following themes mentioned by Holton: conservation (of mass, energy, etc.), mechanicism, " ... macrocosmos-microcosmos correspondence, inherent principles, teleological drives, action at a distance, space filling media, organismic interpretations, hidden mechanisms, or absolutes of time, space, and simultaneity",

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[47] Kuhn *TSSR*, 1, 2; cp. J. Agassi 'Towards an historiography of science' in *Hiostory and Theory*, Beiheft 2, 1963; for an extensive discussion of Kuhn's views, see I. Lakatos, A. Musgrave *Criticism and the Growth of Knowledge* (1970), London, 1974; Finocchiaro *History of Science as Explanation.*
[48] Kuhn *TSSR*, 10, 23.
[49] Kuhn *TSSR*, 4.
[50] Kuhn *TSSR*, 5.
[51] Kuhn *TSSR*, 5.
[52] Kuhn *TSSR*, 6.
[53] Holton *Thematic Origins*, 190; see also Holton *The Scientific Imagination*, Ch. 1.

"…the efficacy of geometry, the conscious and unconscious preoccupation with symmetries."[54]

For Kuhn, "A paradigm ... is in the first place, a fundamental scientific achievement and one which includes both a theory and some exemplary applications to the results of experiment and observation. More important, it is an open-ended achievement, one which leaves all sorts of research still to be done. And, finally, it is an accepted achievement in the sense that it is received by a group whose members no longer try to rival it or to create new alternatives to it. Instead, they attempt to exploit and extend it in a variety of ways…"[55] Holton's themes are more or less orthogonal to the "contingent plane" of "propositions concerning empirical matters of fact (which ultimately boil down to meter readings) and propositions concerning logic and mathematics (which ultimately boil down to tautologies)."[56] "A *thematic position* or *methodological thema* is a guiding theme in the pursuit of scientific work, such as the preference for seeking to express the laws of physics whenever possible in terms of constancies, or extrema (maxima or minima), or impotency ('It is impossible that … ')"[57] Holton also distinguishes thematic components of concepts such as force or inertia, and thematic propositions or thematic hypotheses, containing one or more thematic concepts, and which may be a product of a methodological theme.[58] As a result, Holton's themes have a more persistent character than Kuhn's paradigms: "Only occasionally (as in the case of Niels Bohr) does it seem necessary to introduce a qualitatively new theme into science".[59]

Feyerabend goes even further. Whereas both Kuhn and Holton accept the historical fact of the existence of paradigms, themes, and normal science, Feyerabend insists that the latter is dogmatic, since it clings to a single paradigm.[60] He pleads for

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[54] Holton *Thematic Origins*, 24, 25, 27.
[55] T. S. Kuhn 'The function of dogma in scientific research' in Brody (ed.) *Readings in the Philosophy of Science*, Englewood Cliffs, NJ, 1970, 363; it is by no means easy to comprehend the meaning of Kuhn's paradigms. Masterman says that Kuhn (8) uses "paradigm" in not less than twenty-one senses.
[56] Holton *Thematic Origins*, 21.
[57] Holton *Thematic Origins*, 28.
[58] Holton *Thematic Origins*, 28.
[59] Holton *Thematic Origins*, 29; also Holton *Thematic Origins*, 61ff
[60] Feyerabend 'Problems of empiricism' in R. G. Colodny (ed.) *Beyond the Edge of Certainty*, Englewood Cliffs, NJ, 1965, 172: "Normal science, extended over a considerable time, now assumes the character of stagnation, a lack of new ideas; it seems to become a starting point for dogmatism and metaphysics. Crises, on the other hand, are now not accidental disturbances of a desirable peace; they are periods where science is at its best, exhibiting as they do the methods of progressing through the consideration of alternatives". See also K. Popper 'Normal science and its dangers' in Lakatos and Musgrave, 51-58 and J. Watkins 'Against normal science' in Lakatos and Musgrave, 25-37. Contrary to this, Kuhn 'The function of dogma in scientific research' in Brody (ed.), 364 states: "Advance from

openmindedness, for competing views. It appears, at least from a Kuhnian perspective, that he wishes to return to the pre-paradigm period of science.[61] Feyerabend strongly attacks the "restrictive conditions" of consistency and meaning invariance, present in contemporary positivist empiricism: "Only such theories are then admissible in a given domain which either *contain* the theories already used in this domain, or which are at least *consistent* with them inside the domain; and meanings will have to be invariant with respect to scientific progress; that is, all future theories will have to be framed in such a manner that their use in explanations does not affect what is said by the theories, or factual reports to be explained."[62]

Insofar as it is assumed that sense data are independent of theories, and that the accumulation of new data cannot give rise to a change in meaning of older theories, meaning invariance is a leading motive in positivism. Criticism of this view by Kuhn, Holton, and Feyerabend is based on historical grounds. These writers give many examples which show that any change of "paradigm" implies a change in meaning, also with respect to "observational facts".

We have argued that "meaning" is determined by the relation of law and subject, i.e., everything created has dependent meaning, as a result of being subjected to law by its Creator. Dooyeweerd formulates this in the phrase "Meaning is the mode of being of all that is created".[63] However, this does not imply another kind of "meaning invariance". Indeed, it is precisely in the opening-process that meaning is both deepened and relativized. From our perspective, we would paraphrase Kuhn's theory as follows: In the pre-paradigm phase, scientists are not yet aware of the meaning of their concepts. With the formation of the first paradigms, it is mainly the retrocipatory analogies of the modal aspects or typical structures that are discovered (this includes the search for objectivity, described in Sec. 1.6). Paradigm change is brought about by

paradigm to paradigm rather than through the continuing competition between recognized classics may be a functional as well as a factual characteristic of mature scientific development".

[61] P. K. Feyerabend 'How to be a good empiricist' in Brody (ed.), 320, 321: "You can be a good empiricist only if you are prepared to work with many alternative theories rather than with a single point of view and 'experience'. This plurality of theories must not be regarded as a preliminary state of knowledge which will at some time in the future be replaced by the One True Theory". See also Feyerabend *Against Method*

[62] Feyerabend 'Problems of empiricism' in Colodny, 164; 'How to be a good empiricist', 323; the latter text reads "phrased" instead of "framed". See also N. Bohr 'Discusssion with Einstein on epistemological problems in atomic physics' in P. A. Schlipp (ed.) *Albert Einstein, Philospher-Scientist* (1949), New York, 1959, 209, 210.

[63] Dooyeweerd *NCTT* (vol 1) 4.

the discovery of either a new retrocipatory analogy or, even more spectacularly, by the discovery of an anticipatory analogy. Such discoveries are made possible by an increasing degree of abstraction and, simultaneously, the opening up of new typical structures, both theoretically and technically."[64]

Such developments account for the appearance of "scientific revolutions" as well as Holton's more persistent "themes". With the opening up of a modal aspect, the latter remains in existence, as a fundamental and irreducible mode of explanation, though it may be viewed in a different light. Thus, whether we use Euclidean or non-Euclidean geometries, the aim of geometry remains to account for spatial relations. The description of typical individuality structures in modem quantum physical terms requires the modal aspects with both their retrocipations and their anticipations, which, to a large extent, are describable in classical physical terms. We shall discuss several examples of this model.

Our first example is taken from the history of number theory. After the initial establishment of the meaning of number, the negative and rational numbers are introduced by abstraction. Only then are the real numbers and vectors found by anticipation. Similarly, in the history of geometry, the opened-up investigation of spatial magnitudes in the Pythagorean school was of revolutionary significance. The introduction of non-Euclidean and non-metrical space, multi-dimensional space, formalization of geometry are further examples of the opening up of the spatial modal aspect. In kinematics the development of both the Galilean and Einsteinian principles can be fully accounted for in our theory of the opening-process. As we shall see, the history of astronomy, of physics, and of chemistry are full of examples of sudden increases in understanding due to developments in retrocipation, anticipation, abstraction, and specification. From our vantage point, the fact that Kuhn discovers paradigmatic, revolutionary developments, and that Holton stresses the persistence of themes *in* the history of science, is understandable.

[64] Cf. Lakatos' "research programme", Lakatos 'Falsification and the methodology of scientific research programmes' in Lakatos and Musgrave, 91-196. Lakatos' theory of research programmes, each with a "hard core" and "positive and negative heuristics" is directed to the rational understanding of the driving motive of individual scientists or groups of scientists. Hence it is not very useful for our purpose, which is the understanding of the historical development in a more general sense. Besides, Lakatos' theory lacks any insight into the creational order, to which the historical development of science is subjected.

We now turn our attention to a new aspect of the problem of meaning. Does meaning change *if* it is opened up, and, if so, to what extent does it change and to what extent does it remain invariant? We shall show that not only does the opening-process add (anticipatory analogies) to a modal aspect, but it simultaneously influences the nuclear meaning of the aspect, together with its retrocipatory analogies. This process we refer to as *deepening and relativizing* the original meaning of a modal aspect, since in this way the aspect becomes related to later modal aspects. Our position is more complicated than either "meaning invariance" or "meaning relativism". It involves both the law side and the subject side of reality.

As an example, let us consider the concept of mass.[65] This concept was introduced first by Kepler and Galileo, but became paradigmatic only with Newton. One of the properties of mass is its conservation in chemical reactions (which, incidentally, was justified empirically long after Newton's time). This characteristic of mass is challenged in Einstein's theory of relativity (cf. Sec. 3.8). Now, one may ask whether the meaning of mass has undergone change or not? Positivists will reply that, since the factual content of the sense data related to mass has not changed, its meaning must remain invariant. Extreme operationalists will say that, as there are different experimental methods to determine mass, there are different meanings of mass which are independent of theory, and the meaning of mass will remain invariant with respect to change of theory. Feyerabend, among others, replies that any experimental method is "theory laden" and, hence, "operational meanings" are variable with theories. He states that, since mass is subject to different laws in Newtonian physics than in relativity physics, its meaning has also radically changed.[66]Still others point out that relativistic mass shares at least some of the properties of classical mass, such that some sort of family resemblance exists between the two.[67]

A view, commonly held in physics, is that Newtonian mechanics is a limiting case

[65] Cp. Feyerabend 'How to be a good empiricist', 325ff; Kuhn *TSSR*, 98ff; M. Hesse *The structure of Scientific Interference*, London, 1974, 64ff.

[66] Feyerabend 'Problems of empiricism' 169: "That the relativistic concept and the classical concept of mass are very different indeed becomes clear if we also consider that the former is a *relation,* involving relative velocities between an object and a coordinate system, whereas the latter is a *property* of the object itself and independent of its behaviour in coordinate systems... . The attempt to identify the classical mass with the relativistic rest mass is of no avail either, for although both may have the same *numerical value,* they cannot be represented by the same concept". For a similar viewpoint, see Kuhn *TSSR*, 101, 102.

[67] Cf. Kuhn *TSSR,* 45; Hesse *Structure of Scientific Interference*, 46-48, 64-65; Hesse observes that the classical and relativistic theories could not even be compared if key concepts like mass had completely different meanings in the two theories.

of relativity physics, since, at low velocities, the relativistic and Newtonian formulas become approximately equal. The relevance of this statement becomes clear only if we remember that experimental measurements always have a finite accuracy. Within given limits of accuracy, it is rather easy to determine the velocity below which it is impossible to distinguish Newtonian from relativistic results. A positivistic interpretation will say that, since in this case there is no difference between the two theories, the meaning of terms such as mass must also be the same. A realistic interpretation will insist that the meaning of mass is different in the two theories. We reject both these views.

As we shall argue in Chapters 4 and 5, Newtonian physics has a mainly retrocipatory character, whereas relativity physics concerns the kinematic opening up of the numerical and spatial modal aspects. This opening up also has a bearing on the numerical and spatial analogies of the physical modal aspect, e.g. on mass. The meaning of mass in Newtonian physics can be understood as a numerical retrocipation in the physical modal aspect. In relativity physics, this retrocipation is also opened up, inasmuch as all numerical and spatial relations become frame-dependent. But, as we have already emphasized, this state of affairs implies neither a meaning invariance (since the meaning does change), nor a loss of meaning (since it remains a retrocipatory analogy in the physical aspect). Rather, the opening-process in relativity physics results in a *deepening* and *re/ativizing* of the original closed meaning of mass in Newtonian physics. Relativizing does not result in a loss of meaning, especially since the retrocipatory viewpoint remains valid and useful. Indeed, there are so many instances where Newtonian mass is still relevant that it is illegitimate to characterize the Newtonian interpretation as approximately true, but formally false.

Our twofold use of the retrocipatory *and* the anticipatory, the modal *and* the typical concepts can be compared with HoIton's " ... juxtaposition of the thema-antithema ... couple of atomism and the continuum …"[68] This view promises to be helpful for understanding many related problems in the history of physics, including quantum mechanics. In a similar manner, we shall try to understand the problematic concepts of complementarity, wave-particle duality, correspondence (the relation of classical, modal physics to quantum, typical physics), potential and actual states, thing-like and

[68] Holton *Thematic Origins*, 13, 25.

event-like, thermodynamics and statistical physics, classical and quantum probability theory, motion and current, force and field.

It should be clear that our theory of the opening-process does not lead to "meaning relativism", which is unmistakably present both in Feyerabend's publications and in operationalism. Both in closed and in opened-up form, meaning is bound to law. We, who study law and its relation to the subject side of reality, are similarly bound to law. We find, however, that in the opening-process not only the subject side but also the law side is involved: that is why *meaning* is opened up, and why the meaning of an opened-up modal aspect or typical structure cannot be the same as the meaning of one that is still closed.

1.8 Science and religion

Explicitly, we have presented the following *aims of science:* (1) the explication of laws, and (2) the reduction and deduction of laws (Sec. 1.3); (3) abstraction or analysis, and (4) reconstruction or synthesis of typical laws (Sec. 1.4); (5) the designation of modal aspects and the exploration of retrocipations and anticipations (Sec. 1.5); (6) objectification (Sec. 1.6). We could add a seventh: (7) the explanation of individual facts and phenomena.[69] We can generalize the goals of science by stating that *the aim of science is the theoretic opening up of the full creation*, as discussed in Sec. 1.7.

In addition to the theoretical opening-process, we also find many other opening-processes within the creation. There is a natural opening-process (the temporal evolutionary development of the cosmos); individual ones (the growth, flowering and decay of a plant, or the opening up of the experiential horizon of an animal or man); a technical opening-process (the opening up of possibilities laid down in the creation); an artistic one, a social one, a linguistic one, etc. In each of these cases, we expect that the four basic directions of retrocipation and anticipation, abstraction and specification will be retraceable.

The distinction of law and subject is itself directed. Subjects do not exist without laws, and via the laws they acquire *meaning* as creatures. The direction of subject-to-law points to the origin of creation, the sovereign Creator and Lawgiver, who Himself is subject to no law. As viewed from the subject side, the law is the boundary of

[69] Popper *OK* .

created reality, across which no subject can step. For God, the law is not a boundary,[70] but, by maintaining His laws, according to His covenant, He remains faithful to His creation.[71] Thus the direction of law-to-subject expresses the dependence of the creation upon its Creator (see page 23). The unfolding-process becomes meaningful only because of this two-fold law-subject relation.

The latter statements are clearly not of a scientific character. We have arrived at an interesting and illuminating state of affairs, which displays both the similarity and the distinction of science and religion.[72] In both cases man, who is himself a subject, searches for truth, truth about reality and about himself. In both cases the attitude of man is directed toward the origin of creation, and, therefore, in both cases, his attention is directed toward the law side of reality. The distinction of the two cases lies in the fact that in his scientific attitude, man sees the subject side "reflected" in the law side. As soon as a scientist formulates a law (finds a law conformity), he must verify it (or falsify it) on the subject side. One may even go as far as Popper who says that no law statement should be called scientific unless it is potentially falsifiable.[73]

Man, however, experiences that his scientific attitude is not sufficient for finding the full truth about reality. Through science the origin of creation cannot be found: the law side as the boundary of reality cannot be penetrated. It is in his religious attitude that man seeks to look beyond the laws. In this effort no principle of verification can help him because any subject points to the law side and beyond for its full religious meaning. At this point human self-insufficiency becomes abundantly clear. Faithful knowledge about the origin of full reality requires revelation, the truth of which man can only find in faith. However, as we have pointed out earlier, the scientific attitude also rests on faith. The fundamental hypothesis of all sciences - the hypothesis that reality is lawful - cannot be proved; it must be believed. If you don't believe it, you cannot be a scientist.

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[70] Dooyeweerd *NCTT* (vol 1), 99.
[71] Dooyeweerd *NCTT* (vol 1), 93.
[72] By religion is understood " ... the innate impulse of human selfhood to direct itself toward the *true* or toward a *pretended* absolute Origin of all temporal diversity of meaning, which it finds focused concentrically in itself. This description is indubitably a theoretical and philosophical one, because in *philosophical reflection* an account it required of the meanings *of* the word 'religion' in our argument". (Dooyeweerd *NCTT* (vol 1), 57).
[73] Popper *LSD*, 41; see also Lakatos 'Falsification and the methodology of scientific research programmes'. A similar view was already expressed by Claude Bernard, cf. L. Kolakowski *Positivist Philosophy* (1966), 93. The distinction of falsification and verification reflects the law-subject relation. Scientific law statements (or "all-statements") should be falsifiable, whereas subjective existential statements (of the form "there is a ... ") should be verifiable in order to qualify as empirically meaningful. See Popper *LSD*, 70.

If the sovereignty of God as Creator and Lawgiver is not recognized, the unity and origin of reality must be found somewhere within temporal reality itself. In western culture, it is always man himself who is assigned the task of locating this origin, and, not recognizing . the true origin, he must seek his point of reference in either one or another of the modal aspects, or in one of the typical structures. Such selection of reference points has resulted in the formation of the various mutually irreconcilable schools of philosophy, each pretending to be able to explain everything according to a single principle (see page 6). Alternatively, people may place their trust in power (economic or political), in the church, or in one of the arts.[74] Regardless of where the reference point is chosen, such a choice always leads to a dogmatic (and non-provable) over-rating of the aspect or structure concerned. A balanced and dynamic view of reality can only be achieved if the dependent and self-insufficient character of creation, of which no aspect or typical structure is overestimated or neglected, is accepted.

[74] Or in astrology, superstition, myths, etc. That these convictions cannot be ruled out by their supposed lack of empirical support has been shown by Feyerabend 'Problems of empiricism'; cf. Kuhn *TSSR*, 2; 'Logic of discovery of psychology of research: reflections on my critics' in Lakatos and Musgrave.