PHILOSOPHICAL PROBLEMS IN PHYSICAL SCIENCE

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PHILOSOPHICAL PROBLEMS IN PHYSICAL SCIENCE

by

HERBERT HÖRZ
HANS-DIETER PÖLTZ
HEINRICH PARTHEY
ULRICH RÖSEBERG
KARL-FRIEDRICH WESSEL

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ERWIN MARQUIT

on the basis of a translation by
Salomea Genin

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EDITOR'S FOREWORD

This book is the first broad survey in English of philosophical problems in the physical sciences written from the viewpoint of Marxist-Leninist philosophy. It examines in detail questions such as the nature of physical concepts, physical properties and quantities, and causality and law. The power of Marxist-Leninist philosophy as an analyzing and synthesizing tool is clearly demonstrated, for example, in the discussion on causality, in which not only the difference between causality in Newtonian mechanics and quantum mechanics is discussed, but also the connection between them.

Even in the socialist countries a book of such broad scope on philosophical questions in classical and modern physics is a rarity, and we owe its existence to the recognition by scholars and pedagogues in the German Democratic Republic (GDR) of the importance of philosophy in the training of scientific personnel. As a rule, the university programs in the socialist countries offer their students, regardless of the field of specialization, a general course on Marxism-Leninism, an important component of which is Marxist-Leninist philosophy. Much rarer, however, are courses on philosophical problems encountered within a given field of specialization. It was precisely for such a course, intended for students preparing for teaching careers in the physical sciences, that the German edition of this book was written by a team of outstanding GDR philosophers of natural science headed by Professor Herbert Hörz of the Academy of Sciences of the GDR and Professor Hans-Dieter Pöltz of the Pedogogical Higher School at Erfurt.

The original text was written for students who already had academic training in Marxist-Leninist philosophy. The present edition, however, is intended for faculty, graduate students, and researchers in the physical sciences and philosophy of natural science. Scientific workers with training in classical and quantum physics should not find the material in the book excessively difficult. Some previous contact with philosophy will be helpful, but not absolutely necessary, since brief expository material has been added as footnotes or incorporated into the text.

In several places in the original text the treatment of one or another philosophical question led to ideological discussions, usually connected with the role of physical-science teachers in a socialist country. Where it did not seem artificial these discussions have been generalized in the present edition so as to be of interest to readers who do not see themselves primarily as teachers. Often, however, these passages simply have been dropped, especially if they were intended specifically for teachers in the GDR.

Some brief remarks on the structure of Marxist-Leninist philosophy will be helpful to readers not already familiar with it. The term *Marxism-Leninism* is applied to three interconnected areas which were characterized by Lenin as *philosophy*, *political economy*, and *scientific socialism*. The latter treats the transition from capitalism to socialism as a law-governed process and is contrasted with *utopian socialism*. In the socialist countries the term *scientific communism* is used instead, since the concern in these countries is the laws of transition from the lower stage, socialism, to the higher stage, communism, of what is generally referred to as the *communist socioeconomic formation*.

Marxist-Leninist philosophy, also, can be regarded as consisting of three components: *dialectical materialism*, *historical materialism*, and the *dialectical-materialist theory of knowledge*. Historical materialism is concerned principally with the Marxist-Leninist theory of development and history of society, including the formation of social consciousness. Its relevance to the development of the physical sciences is discussed in the book. The theory of knowledge is dealt with in great detail throughout the book.

The original edition already contained a brief summary of the principal features of the Marxist-Leninist concept of philosophical materialism. This concept becomes increasingly clear as one progresses through the book. On the other hand, there was no corresponding initial exposition of the fundamental ideas behind materialist dialectics. For this reason, a brief summary of its principal features was added by the editor in the first section of chapter 1, along with some additional remarks later in the same section. These insertions can be readily recognized, since they are printed in smaller type.

A brief introduction, similarly set off in smaller type, has been added by the editor to the second section of chapter 5. This section deals with a critique of specific forms of realism often encountered by students in West German schools and is therefore of special interest to teachers in the GDR. The editor's introduction summarizes some general features of philosophical realism and will help establish the relevance of the more specialized critique for the readers of the English-language edition.

In general, the editor did not intentionally modify any of the ideas of the authors. Revisions were made entirely in the interest of clarity, to take into account the range of differences in background between readers in the GDR, for whom the original edition was written, and those likely to be reading the English-language edition.

The revisions of the original text for the English-language edition and explanatory footnotes were made by the editor with the concurrence of the authors. Ultimate responsibility for differences in the two editions, however, rests with the editor of the present edition.

The editor and the Marxist Educational Press express their gratitude to Professor Manfred Buhr of the Academy of Sciences of the GDR for arranging the translation of the book and to the publisher of the German edition, the Deutscher Verlag der Wissenschaften, for making this edition in English available through the Marxist Educational Press. The editor also expresses his gratitude to Dr. Ulrich Röseberg for many fruitful discussions on the conceptual foundations of physics during a sabbatical year the editor spent in the GDR. The translator, Salomea Genin, is especially thanked for the high quality of her translation and for her numerous suggestions for improving this edition.

University of Minnesota Erwin Marquit
January, 1980

AUTHORS' PREFACE

The need for cooperation between Marxist-Leninist philosophers and natural scientists, demonstrated so well in the past by Marx, Engels, and Lenin, is even more important today. This applies both to the solution of problems of world view, epistemology, and methodology connected with the sciences, as well as to the further development of dialectical materialism and the natural sciences. The development of the relationship between Marxist-Leninist philosophy and the natural sciences is exceedingly complex and complicated. It continually unearths new scientific and methodological questions which are highly relevant for a world view, and therefore any tendency to oversimplify must be combated. This process of development can unfold in a meaningful way only if a broad spectrum of persons, and not only a limited group of highly skilled specialists, has sufficient knowledge about an individual scientific field and philosophy and understands the interconnections between them.

The more general problems of Marxist-Leninist philosophy and the natural sciences described in the first part of the book are the foundation for those questions of philosophical materialism, materialist dialectics, and the theory of knowledge that are discussed in close connection with the problems of physics in the chapters that follow.

A final chapter contains a critique of some currents in bourgeois natural philosophy particularly relevant to philosophical problems of physics.

We wish to thank the editor, Professor Erwin Marquit, and the Marxist Educational Press for the care they took in preparing the English-language edition of this book.

Berlin and Erfurt
January, 1980

Herbert Hörz
Hans-Dieter Pöltz
Heinrich Parthey
Ulrich Röseberg
Karl-Friedrich Wessel

Chapter One

THE INTERACTION OF MARXIST-LENINIST PHILOSOPHY AND THE NATURAL SCIENCES

1. Marxist-Leninist Philosophy as a Foundation of a World View, Epistemology, and Methodology for the Natural Sciences

Dialectical and historical materialism is, along with political economy and scientific socialism/communism, one of the three components of the scientific world outlook of the working class.[1] When investigating the details of the relationship between Marxist-Leninist philosophy and the natural sciences in general, and physics in particular, one must not lose sight of the unity of the Marxist-Leninist world view. All three components of Marxism-Leninism contribute answers to questions about the origins and structure of the world, the source of knowledge, the position of human beings in the world, the meaning of life, and the character of social progress; and this contribution is made in conjunction with progress in science and the practical experiences of humankind.

The historical function of the Marxist-Leninist view is to provide a theoretical orientation for the practical activity of the working class on the basis of the objective laws of development. The criterion for its truth is practice, and that is why it is not a faith, but a science. And what applies to Marxism-Leninism as a whole also applies, of course, to its theoretical foundation: Marxist-Leninist philosophy.

This philosophy was founded by Karl Marx, Frederick Engels, and Vladimir I. Lenin, as the generalization of the development of science (including the history of philosophy and the natural sciences) and of society. According to Marx, the key to understanding the development of the natural sciences and, in particular, the relationship between philosophy and natural science lies in political economy. He writes:

> The *natural sciences* have developed an enormous activity and have accumulated an ever-growing mass of material. Philosophy, however, has remained just as alien to them as they remain to philosophy. Their momentary unity was only a *chimerical illusion*. The will was there, but the power was lacking. Historiography itself pays regard to natural science only occasionally, as a factor of enlightenment, utility, and of some special great discoveries. But natural science has invaded and transformed human life all the more *practically* through the medium of industry; and has prepared human emancipation, although its immediate effect had to be the furthering of the dehumanisation of man. *Industry* is the *actual*, historical relationship of nature, and therefore of natural science, to man. If, therefore, industry is conceived as the *exoteric* revelation of man's *essential powers*, we also gain an understanding of the *human* essence of nature or the *natural* essence of man. In consequence, natural science will lose its abstractly material — or rather, its idealistic — tendency, and will become the basis of *human* science, as it has already become — albeit in an estranged form — the basis of actual human life, and to assume *one* basis for life and a different basis for *science* is as a matter of course a lie.[2]

Marx did not stop at describing the social significance of the natural sciences. He used the philosophical generalization of the results of the natural sciences for his general scientific work. This is expressed in a letter to Lassalle dated January 16, 1861: "Darwin's book is very important and it suits me well that it supports the class struggle in history from the point of view of natural science. . . . Despite all deficiencies, it not only deals the death blow to 'teleology' in the natural sciences for the first time but also sets forth the rational meaning in an empirical way."[3]

In the foreword to the second edition of *Anti-Dühring*, published in 1885, Engels writes: "But a knowledge of mathematics and natural science is essential to a conception of nature which is dialectical and at the same time materialist."[4] In many of his works he demonstrated just how philosophy and natural science are interconnected. Writing about the necessity and purpose of such work, he comments: "It goes without saying that my recapitulation of mathematics and the natural sciences was undertaken in order to convince myself also in detail — of what in general I was not in doubt — that in nature, amid the welter of innumerable changes, the same dialectical laws of motion force their way through as those which in history govern the apparent fortuitousness of events; the same laws which similarly form the thread running through the history of the development of human thought and gradually rise to consciousness in thinking man."[5] Engels had no previous work on this subject to rely on and set himself the task of proving that dialectical laws, the dialectics of nature, are to be found in every science. "But to do this systematically and in each separate department, is a gigantic task,"[6] wrote Engels. In his article, "On the Significance of Militant Materialism," Lenin explained the necessity of an alliance between philosophers and natural scientists, and he set tasks which are still topical: "Greater attention should be paid to it. It should be remembered that the sharp upheaval which modern natural science is undergoing very often gives rise to reactionary philosophical schools and minor schools, trends and minor trends. Unless, therefore, the problems raised by the recent revolution in natural science are followed, and unless natural scientists are enlisted in the work of a philosophical journal, militant materialism can be neither militant nor materialism."[7]

Cooperation between Marxist-Leninist philosophers and natural scientists in the spirit of Marx, Engels, and Lenin means making Marxist-Leninist philosophy the foundation for the epistemological and methodological approach to research in the natural sciences. This cooperation also contributes to the further development of Marxism-Leninism through philosophical analysis and generalization of the results obtained in the individual scientific fields.

The test of Marxist-Leninist philosophy is social practice and its contributions to the development of all sciences. Together with the other parts of Marxism-Leninism, this philosophy fulfills three closely interlinked functions in regard to the natural sciences. As a *world view* it provides a unified philosophical orientation for research in the natural sciences, rejecting unscientific philosophical speculation as well as positivist claims that questions of world view are scientifically unanswerable and meaningless questions. Marxist-Leninist philosophy can fulfill this function only if it is able to generalize philosophically new knowledge in the natural sciences in such a way that the scientific world view itself becomes more profound, and its superiority over idealist and mechanical-materialist approaches to natural science is demonstrated with ever-greater clarity.

This function of Marxist-Leninist philosophy is closely linked with its *heuristic function*. In the development of the natural sciences, Marxist-Leninist philosophy is heuristically effective if it succeeds in utilizing the philosophical knowledge of the natural scientist and the cooperation between natural scientists and philosophers for the acquisition of new knowledge. The encouragement given in the socialist countries for cooperation among philosophers and natural scientists has its origins in the attention paid to the question by Lenin, who stressed its theoretical and practical importance. Through its specific possibilities for criticism of concepts, formation of hypotheses, and generalization, philosophy is able to play an important role in the acquisition of scientific knowledge. By fulfilling its heuristic function, Marxist-Leninist philosophy provides an epistemological and methodological foundation for natural science. Since it also does the same for the development of the social sciences and the technologically oriented sciences, it deepens our understanding of the unity of the sciences without ignoring the specific features of the individual fields of scientific work.

Dialectical and historical materialism, together with the other two components of Marxism-Leninism (political economy and scientific socialism/communism), forms the theoretical basis for policies followed in socialist societies and serves as a scientifically based guide to practical action. In this sense, the philosophy also has an *ideological function* affecting the development of the natural sciences. In providing the basis for scientific cognition of objective reality it forms motives and attitudes and promotes social action in the interest of progress, making it possible for individuals to integrate their personal experiences in society within a scientific world view. It enables the individual natural scientist to answer the ethical and moral questions faced by natural scientists in connection with the development of their science and its application in society.

The effectiveness of Marxist-Leninist philosophy, of Marxism-Leninism in its totality, depends on how the three functions are brought together and integrated. This effectiveness is reduced if any of these functions is isolated from the others, let alone if it is ignored altogether. The philosophical process of generalization is of focal importance for fulfillment of the functions of Marxist-Leninist philosophy in connection with the natural sciences. Before we can examine this process of generalization more closely, we will detail briefly some important aspects of this philosophy.

Marxist-Leninist philosophy approaches the problem of the origin and structure of the world as a whole and the source of knowledge about it in a consistently materialist way. Its basic position is that matter is primary to the mind, is neither creatable nor destructible. Everything which exists outside and independently of the mind, and can be reflected by it, is matter. The unity of the world lies in the unity of matter, and the objective interconnections among nature, society, and human thought are nowhere interrupted. The sciences investigate the law-governed connections of selected fields of objective reality and reflect the dialectics of objective structures in their real connections, in their motion and development. The source of our knowledge is the objectively existing connections which are outside and independent of our minds. Matter and consciousness cannot be metaphysically torn apart. Consciousness can never be defined as the logical negation of matter or vice versa. Therefore a consistent materialism can only be dialectical. Consistent philosophical materialism means not only the recognition of the primacy of matter over mind, but also recognition of the material unity of the world and the existence of objective laws in nature and society.

Materialist dialectics is the "science of universal interconnection,"[8] the science "of the general laws of motion and development of nature, human society, and thought."[9] In taking into account the objective interconnectedness of all phenomena and processes, dialectics distinguishes three principal laws of the most universal kind: the law of transformation of quantitative changes into qualitative changes and vice versa, the law of the unity and struggle (or interpenetration) of opposites, and the law of the negation of the negation.

The dialectical conception of development lies in understanding development not as simple quantitative change, but as a process in which quantitative changes lead to qualitative changes, the latter opening up the path to further quantitative changes, hence the name *law of transformation of quantitative changes into qualitative changes and vice versa*. In any transformation process the old qualities vanish and new qualities appear. But the destruction of the old qualities is not all-embracing. Some are carried over into the new state, but occur now under different conditions. For example, in the decay of a neutron into a proton, electron, and neutrino we are still left with a nucleon, and the system of decay products still has no net electric charge. In other words, the process of qualitative change involves destruction with an aspect of preservation, a concept that is embraced by the terms *sublation* or *dialectical negation*.* The concrete form of qualitative change depends on the specific conditions in which the change takes place. Changes may be gradual or relatively sudden and therefore embrace a unity of continuity and discontinuity. In spite of all gradualness, the transformation to a new state must be considered a leap, a break with the old state — it is the interconnections among the *new* qualities that are decisive for the subsequent course of development.

The law of the unity and struggle of opposites (which can also be expressed nonanthropomorphically as the *law of the unity and interpenetration of opposites*) is the basis for all change. Metaphysical thought viewed pairs of opposites such as *chance* and *necessity*, *universal* and *individual*, *content* and *form*, *essence* and *phenomena* (or *appearance*), and *continuity* and *discontinuity* as mutually exclusive *philosophical categories*, each member of the pair standing in isolation from the other and never occurring simultaneously. Dialectics sees them in their unity and reciprocal interpenetration. Consider, for example, the categories of the *universal* (or *general*) and the *individual*. The term *book* is a universal and is to be distinguished from the individual book at which the reader is now looking. *Book* does not represent one single particular object, but a group of objects, existing and potentially existing, having certain similarities. Nevertheless, the universal does not exist only in thought, since universals are a source of interconnections among things. An individual book differs from other individual books and that is why they are individuals; but at the same time, individual books resemble one another in some aspect, they possess certain properties in common. That is what makes *book* a universal. Differences and unity are inherent in objects and processes and express their relationship to themselves and to other things and processes. The dialectical unity of the individual and the universal is the basis for theoretical generalization and for the practical utilization of the results of such generalization.

In the view of materialist dialectics, all structures, and the processes that embrace them, arise out of the unity and interpenetration of dialectical opposites (also called *dialectical contradictions* when the aspect of interpenetration is to be stressed). The unity of opposites forms the basis of the relative stability of phenomena. The opposition is relative, since one thing is an opposite only in relation to something else. When two opposites constitute a unity, their interaction or interpenetration produces a change in this unity, that is, the objective reality itself undergoes change. In this sense, the "struggle" is absolute.[10] The struggle of opposites unfolds within a given unity until the incompatibility of the opposing sides, aspects, and tendencies leads to a qualitative change. In the resolution of the "struggle" on one level, a new level of "struggle" emerges on a different basis, under new conditions, and with a different content. The operation of the law of unity and struggle of opposites has been demonstrated in all variety of processes and phenomena in the worlds of nature, society, and thought.

*The term *negation* was already used in a dialectical context by Spinoza: "All determination is negation." In logic *determination* is the rendering of a notion more definite by the addition of attributes. But logical determinations are inseparably connected with objectively real processses in nature, society, and thought, processes leading to new characteristics not present previously. This inseparable connection is recognized in materialist dialectics by the concept of the *unity of the logical and the historical*. Hence dialectical negation is an objectively real process, or the result in thought of such a process, in nature, society, and thought, and is to be distinguished from *negation in formal logic*, which represents a thought process in which the truth value of a statement is changed into the opposite truth value.

The opposites embraced by the law are not limited to structural aspects of a unity, but also embrace the processes that go on within it, expressed through tendencies for the system to develop in one or another direction, ultimately leading to new structural forms.

Conservation laws are one illustration of the operation of the law of the unity and struggle of opposites in physics. Conservation laws establish quantitative conditions for qualitative transformations (though, by themselves, they are not sufficient to establish which changes actually occur). Such laws thus provide for quantitative continuity in the presence of qualitative discontinuity. Apart from this dialectical unity of continuity and discontinuity, the unity of quantity and quality reflected in the laws is itself a dialectical unity of opposites. The quality of a thing is what makes it different from other things. Quantity, however, can reappear in things of most widely differing quality. In a sense, quantity is a destroyer of quality, that is, it is quality negated, or, as Hegel stated it, quantity is sublated quality.[11]

Owing to its decisive role both in the structural characteristics of a system and in the processes that embrace it, the law of the unity and struggle of opposites can be considered to be the most important of the dialectical laws.

The third law, the *law of the negation of the negation*, contains the source of the concept of progress and irreversibility. Development represents a never-ceasing process of dialectical negation, in which certain old qualities vanish while others reappear in new circumstances and surroundings to give qualitatively new states, in a process that is often described as *spiral development*. The fact that the emergence of the new is conditioned on the existence of the old, but not in a mechanically repetitive way, means that, despite the zigzags of history, there is a "general law-governed tendency for development from the simple to the complex, from the lower to the higher, the tendency of *progressive ascending* motion."[12]

The term *objective dialectics* is applied to the dialectics of the objective reality. It is objective in that this reality and its dialectical character are independent of our knowledge or thinking about it. *Subjective dialectics* is the dialectics of thought about the material world and about thought itself. Subjective dialectics embraces the dialectical-materialistic theory of knowledge, including dialectical logic. "Dialectics is not only a theory (of objective and subjective dialectics), but also a method. It is the method of the systematic and conscious application of laws and principles of dialectics for the practical and theoretical appropriation of the material world."[13]

All research in the natural sciences is necessarily tied to a consistent philosophical materialism, at least in regard to phenomena in a given field. This certainly does not mean that the natural scientists must consciously accept dialectical materialism. They can carry on their research even if they hold idealist views outside their field of specialization. In class-divided societies the social context within which science develops often leads to attempts to transfer unjustifiably to a given field of science the philosophical positions acquired outside the field. In all cases where natural scientists explicitly take idealist positions, it can be fairly easily shown that there is a contradiction between the implicit philosophical assumptions of their work and their views about these assumptions.

Heisenberg, for example, repeatedly speaks of modern atomic physics being the definite proof of Plato's victory over Democritus.[14] He notes that in quantum mechanics a mechanistic-materialist representation of the atom is very much out of place and that mathematics has come to play a fundamental role in the development of quantum mechanics. If, for this reason, he prefers idealism to materialism as a philosophical theory, this no longer has anything to do with his physical theories, but simply expresses a world view which he acquired during the course of his bourgeois-humanist education and which he deepened and consolidated in his further life, but which is quite independent of physics. When working on quantum mechanics he assumed that the objects whose laws he investigated as a physicist existed outside and independently of consciousness and that their general, necessary and essential properties and relations could be reflected in our consciousness. Had he assumed the opposite and had he been consistent about it, he would not have been able to develop a physical theory for which the criterion of truth is experiment and observation. Today it is often claimed that his attempt to find a unified elementary particle theory is due to his idealist convictions. This would be true only if he had relied upon the mathematical program for this theory to the point that he considered experiment and observation superfluous to high-energy physics. Of course, progress in physical knowledge

can be made also by means of mathematical programs, as the development of matrix and wave mechanics has shown. However, they become a physical theory only when they can explain and predict experimental data.

The example of Heisenberg's philosophical views shows that spontaneous materialism can arise out of research in the natural sciences. The epistemological roots of idealism, however, can also be found in this research. These roots can grow into a philosophical system if the appropriate socioeconomic conditions for this exist. It is in this sense that one should understand our statement that all research in the natural sciences is tied to a consistent philosophical materialism in a given field. New physical knowledge, such as quantum mechanics, is possible only on the basis of a consistent materialism, even if the scientists involved explicitly hold different views. Abandoning this materialism would mean no longer accepting experiment and observation as criteria for truth, which would make it impossible to construct and uphold a physical theory.

What about objective idealism in the form of religion? Does not religious belief on the part of a natural scientist contradict our statement about materialism being the philosophical requisite for physical research?

Natural scientists who believe in the possibility of arbitrary interference in nature by a supernatural being will, of course, not be working scientifically whenever this possibility is allowed to influence the result of their work. In other words, religion is never a philosophical assumption for research in natural science. However, if the natural scientist assumes that the world was created by a supernatural being, who, at the same time, established the laws which embrace it, then scientific research is again possible. For research in the natural sciences, it is not religious belief which underlies the philosophical foundations for a scientific approach, but the conviction that the world is governed by laws, at least in the fields under investigation. That the world and the laws governing it are the result of an act of creation is a hypothesis that goes beyond scientific research, one that cannot be confirmed by research. Hence it might just as well be abandoned. This takes us back to a materialist position.

Our goal here has not been to "refute" religion with science. What we have argued is that the validity of a religious belief cannot be established by science, nor can such a belief be a requirement for science. *The philosophical basis for physical research is materialism.*

The development of the natural sciences has continually deepened our knowledge about objective dialectics, especially after Engels' *Dialectics of Nature*. Engels and Lenin showed that the spontaneous materialism of the natural scientists is often not enough to resist the force of idealism. Especially in times of scientific revolutions, such as at the turn of the century and in the mid-twenties, there is a great danger that the lack of knowledge among physicists about materialist dialectics — both the objective dialectics of nature as well as the dialectics of the process of cognition — may lead to the abandonment of materialist positions in favor of idealism. A conflict then arises between philosophical materialism, on which scientific research must be based, and the researcher's understanding of these foundations. Conclusions of an idealist nature drawn from developments in science are, as a rule, used by philosophers as supporting evidence for philosophical systems that fulfill a certain function in bourgeois ideology, but which usually have no relation whatever to the development of science.

The basic principles of historical materialism make it possible to incorporate the overall development of science, including natural science, within the larger context of social development.

Because the basic principles of dialectical and historical materialism and of materialist dialectics objectively belong to the philosophical foundations of the natural sciences and afford a scientific explanation for the development of natural science, we speak of Marxist-Leninist philosophy as the foundation for a world view, epistemology, and methodology for the natural sciences. Needless to say, we do not claim that the majority of natural scientists adhere to dialectical and historical materialism. This would neither be historically justified nor agree with present-day facts. To be an adherent of Marxist-Leninist philosophy involves much more than the acceptance of some of its basic principles as a philosophical requisite for scientific research. But even such an acceptance is not characteristic of natural scientists in the capitalist countries today, although the number taking an interest in dialectical materialism is growing constantly. To be considered an adherent of dialectical and historical materialism, a natural scientist must make a profound analysis of the philosophical requisites and consequences of scientific research and study this philosophy, above all, as a generalization of all the sciences and of all experience of social development, including, in particular, the revolutionary traditions of the working class. A materialist approach to nature and an idealist approach to society cannot both arise from the same philosophical foundation. Physics alone will never lead to Marxist-Leninist philosophy, just as philosophy alone does not generate physics.

The statement that Marxist-Leninist philosophy does not generate physics does not mean that this philosophy does not have important consequences for physics. At first glance, this may not be directly evident from the methods used for research in physics. Indeed, in other fields, especially in the social sciences, the connection between Marxist-Leninist philosophy and the results of scientific activity is more readily apparent.

The following explanation can be offered:

A basic function of science is to understand the world in order to produce changes in it, both in the relationship of people to nature and to one another. In class-divided societies the dominant ideas of any epoch are those of the ruling class, since the class that has the means of material production at its disposal has control at the same time over the means of mental production.[15] The principal concern of ruling classes is the preservation of the relations of subordination and domination which characterize exploitative modes of production. Hence it is not in the interest of ruling classes to create a science of social development and social change. Even during periods of social upheaval in which the revolutionary class is another exploiting class (for example, during the transition from feudalism to capitalism), the maintenance of the new relations of subordination and domination (of capital over labor) is viewed as a relationship that is ideal and not destined to change. The philosophical principle of *divine law* was used to justify feudal relations of production; in capitalist (or bourgeois) society the concept of *natural law* became the characteristic philosophical principle. It was implicitly assumed that the laws themselves were not subject to change. A scientific understanding of the laws of social development is, however, an absolute necessity for the transition from capitalism to socialism, where the working class, as the principal revolutionary class, has no material means at its disposal other than its ability to organize itself into a cohesive mass movement on the basis of the theoretical understanding that its historic role is to take control of the means of production and transform it into socially owned property.

Marx, Engels, and Lenin, as leaders of this revolutionary class (although they themselves did not come from this class), took on the task of creating a science of society where no such science had existed previously. The need to develop a science of society with a focus on social change required the elaboration of dialectical materialism as the philosophical basis for the process of change.

The natural sciences, however, have a much longer history as sciences. They were well established as sciences long before the systematization of dialectical and historical materialism as an integrated philosophical system. The impressive successes of Newtonian theory in the spheres of celestial and applied mechanics were of great importance for the development of the technologies of production and transportation and led to the rapid development and consolidation of the scientific methodology on which classical mechanics was based. Despite the fact that this methodology concerned itself principally with change of place produced by external forces and not the internal development of bodies or systems of bodies that were undergoing mechanical motion, it was valid for the study of a broad range of motions of material bodies. What was not valid, as we shall see in chapter 3, was the philosophical generalization that led to a one-sided stress on the unchanging characteristics of all of nature. It was on this level that the influence of the dominant ruling-class ideologies about unchanging social relations was carried over into the philosophies of science.

With the continued development of natural science, inconsistencies between the metaphysical world view (i.e., views based on unchanging essence) and the actual behavior of the physical world became evident. Techniques for accommodating these inconsistencies were also developed. For example, the reductionist approaches that characterize mechanical materialism are useful for studying certain types of relationships among different levels of organization and integration of matter. On the other hand, a complete reduction is not, in principle, possible, so the physical sciences are broken up into a number of subfields, each concentrating on a different level or range of levels: particle mechanics, continuum mechanics, thermodynamics, electricity and magnetism, nuclear physics, atomic physics, physical chemistry, etc., to each of which reductionist techniques are then applied. Within the individual subfields reductionist techniques again prove to be incapable of dealing with wide ranges of problems, and it often becomes necessary to introduce a number of contradictory models such as the collective-oscillation model and independent-particle model of the nucleus. The dialectical character of the relationship among these levels and models is implicit in such approaches, even if it is not explicitly recognized as a philosophical principle. Although pre-Marxist philosophies of science were largely mechanistic when formulated explicitly as philosophies, they were, in fact, eclectic, and scientific practice actually contained many elements that reflected dialectical-materialist principles. This is why scientific progress was possible in the absence of a consciously applied dialectical-materialist methodology of science. The successes achieved under these conditions of philosophical eclecticism also make it difficult for many natural scientists to see the principles of Marxist-Leninist philosophy as the explanation for the success of scientific methods that have been applied in practice. (See also the discussion in subsection 2b of this chapter.)

Analysis of the history of the relationship between philosophy and the natural sciences has shown that any attempt to seek specific

results of the application of a philosophy to the development of a science solely on the basis of the fundamental principles of that philosophy will not be fruitful. This applies both to speculative natural philosophy as well as to other attempts to judge the truth of theories or of particular findings in the natural sciences by means of philosophical principles. Conversely, it is also clear from the historical material that it is not possible to draw direct conclusions about fundamental principles of philosophy from the findings of the individual sciences. This often leads to philosophical short-circuiting.

Today the basic principles of Marxist-Leninist philosophy are available to us. But in order to be able to work with them, we must know how they arose. They are not arbitrary constructions of brilliant philosophers, nor did they enter scientific consciousness through some form of revelation. What they are is the philosophical process of generalization from the practical experiences of humanity during thousands of years of class struggles, and, in particular, from the traditions of the revolutionary working class. But they are also the result of philosophical generalization of research in the individual fields of science on the background of the entire history of philosophy. We are interested in seeing how this process of generalization works for the natural sciences. In other words, what exactly is *philosophical generalization* of the results of natural science? Has the process of philosophical generalization been essentially completed by Marx, Engels, and Lenin, and do all our efforts in philosophical research merely lead us again and again to the confirmation of the basic principles already known to us? What is the object of present-day philosophical research on the new materials of the natural sciences? Can one use results from the analysis of the philosophical process of cognition for discussions on the heuristic function of Marxist-Leninist philosophy in the natural sciences?

Here, a number of questions arise which require us to begin with a discussion of the philosophical process of generalization.

2. Philosophical Generalization of Our Knowledge of Natural Science

We have already emphasized that the generalization of knowledge from the natural sciences was necessary for the further development of Marxist-Leninist philosophy. Philosophical generalization does not mean finding something general, something that all sciences have in common. It means examining such knowledge to see whether it can contribute to answering questions connected with a world view. Marx, Engels, and Lenin arrived at and verified fundamental philosophical principles in this way. However, the value of a single scientific result or of a whole science cannot be measured by the contribution it makes to consolidating philosophical positions. New fundamental knowledge and a new emerging science are usually attractive material for philosophical generalization. Their potential for deepening philosophical understanding is particularly high. Therefore, it is not surprising that the results of basic research are of particular interest for philosophers working on philosophical questions in the sciences. Furthermore, not every science can contribute to the same degree to our understanding of the most fundamental questions of philosophy.

The knowledge gained from physical research can lead to philosophical conclusions about the origin and structure of the world as a whole and contribute to our understanding of the source of knowledge itself. Relativity theory, quantum mechanics, unified "elementary" particle theory, and cosmological models are examples of areas of research where discussions have assumed a philosophical character.

However, attempts were also made to draw conclusions from physics (e.g., from a mechanical-materialist position) about the place of human beings in the world and about the nature of social progress. Certainly such attempts will be repeated. We know, however, that we cannot find the answers to such questions in physics. The laws of social development involve a higher form of motion of matter and cannot be explained in terms of the lower forms of motion investigated by physics. In physics one cannot even sensibly formulate questions about the meaning of life. But this does not make them senseless questions. Too little attention has been paid up to now to the implications of the epistemological analyses in modern physics for one aspect of the place of human beings in

the world, namely, their role in the process of cognition as determined by the *subject-object dialectic*.*

The basic principles of philosophical cognition discovered through philosophical generalization by Marx, Engels, and Lenin are impressively borne out by practical human experience and should be considered to be part of our scientific knowledge.

The fundamental philosophical principles are the starting point for the philosophical analysis of natural science, and they must continually be tested. Therefore, the first step in the philosophical analysis of new findings in natural science is to test the new knowledge for compatibility with the fundamental philosophical principles. In the confrontation of world views, such testing is important in order to refute vulgarized, one-sided or distorted portrayals of dialectical materialism. Consider, for example, the discussions connected with the theory of relativity, where the relativity of space and time in regard to individual motion, i.e., the rejection of the concept of absolute space and absolute time, was used as an argument against materialism. Unfortunately, a number of Marxists at that time also rejected the theory of relativity because they did not objectively analyze the false philosophical arguments.[16] The thesis that space and time are forms of existence of matter† demands a detailed investigation of the dependence of the objective space-time structure on the motion of material objects and expresses the materialist viewpoint that our space-time theories reflect objective relations between space and time. Proof that the theories coincide with the objective relations is a prerequisite for the further philosophical analysis of space-time relations, from which we form our views about the relationship of matter, motion, space, and time. These views then constitute the basis for the recognition of space as an objectively existing structure. One also needs to investigate such questions as the relationship between continuity and discontinuity and the irreversibility of time. But this takes us beyond the basic principles of philosophy.

Because of their generality, the basic principles can provide only a framework for practical activity. They cannot provide clear

*The *subject-object dialectic* refers to the process by which the human mind (the subject) forms its image of objective reality (the object) existing outside the mind.

†"The basic forms of all being are space and time, and being out of time is just as gross an absurdity as being out of space." (Engels, *Anti-Dühring*, p. 64) This question is taken up in chapter 2, section 3, in connection with Lenin's development of Engels' ideas in *Materialism and Empirio-criticism*.[17]

guides to action either in one's daily life or in the development of science. But our aim is to develop our scientific world outlook in such a way that we can draw practical conclusions from it. We can do this only on the basis of our present scientific knowledge and current store of human practical experiences. Strictly speaking, however, every new development takes place with a certain delay, for philosophical research also needs time, and during this time the other sciences do not stand still.

The aim of the philosophical generalization of the results of current research in the natural sciences is to formulate the basic principles of philosophy in such a way that our world outlook is further deepened and that this outlook leads to concrete human actions in all fields.

To be fruitful for natural science, every general philosophical statement must be reformulated for the field in which it is to be used. Let us take a look at the relationship, for example, between law and chance as applied to physics. By the term *law* we understand a general, necessary (i.e., reproducible and essential) connection, that is, a connection determining the character of the phenomena. This definition can be reformulated for classical physics by stating that a law is a possible relation which is necessarily realized in the physical process under the conditions for which the law is valid. A chance occurrence is then the concrete form in which this necessity manifests itself in phenomena — in the tendency toward a given behavior as expressed in fluctuations about the law. This view of a law, as formulated for classical physics, is no longer sufficient for quantum mechanics. New material from the natural sciences demands further refinement of this philosophical concept. The quantum theory would justify the following expression of the concept of law: a law is a general, necessary, and essential connection (basic principle), whereby the possible behavior of the system is necessarily realized (dynamic aspect), but where a number of possibilities exist for the behavior of the elements of the system, and these possibilities are realized at random (stochastic aspect); however, every chance realization of a possibility by an element occurs with a certain probability (probabilistic aspect).* As long as this concept of law is fruitful for physics, but not yet tested in the other sciences, it has a heuristic function in the latter. One can formulate the philosophical hypothesis that this concept of law, acquired from the philosophical generalization of quantum mechanics, is also meaningful for other sciences. Only when this hypothesis has been tested for the other sciences and shown to be valid for them can it be raised to the rank of a philosophical concept.

*This concept of a statistical law is discussed in detail in chapter 3.

This takes us to a further link between general philosophical knowledge, the basic principles, and the corresponding knowledge of natural science, namely, *the philosophical hypothesis*. Tne philosophical hypothesis can be formulated on the basis of a philosophical analysis of the knowledge acquired in the individual sciences. It represents a well-founded presumption of the validity of connection of one science to another. The philosophical hypothesis is a step toward the extension of our philosophical knowledge. The philosophical generalization of knowledge acquired in the natural sciences and the establishing of the connection between world view and the process of cognition in the natural sciences is effected through the philosophical hypotheses. While the aim of philosophical generalization of our knowledge in the natural sciences is the extension of philosophical knowledge, the connection is not a direct one, but involves the basic philosophical principles associated with a world view. There are also a number of links between the established findings and hypotheses of natural science on the one hand and the basic philosophical principles on the other. The basic philosophical principles are not directly confronted by discoveries in natural science, nor can theories in natural science be derived from the basic philosophical principles. Of all existing philosophical links between the basic principles of Marxist-Leninist philosophy and natural science, the philosophical statements and the philosophical hypotheses have been investigated in greatest detail. The possibility of other links cannot be excluded, but this requires further philosophical investigation.

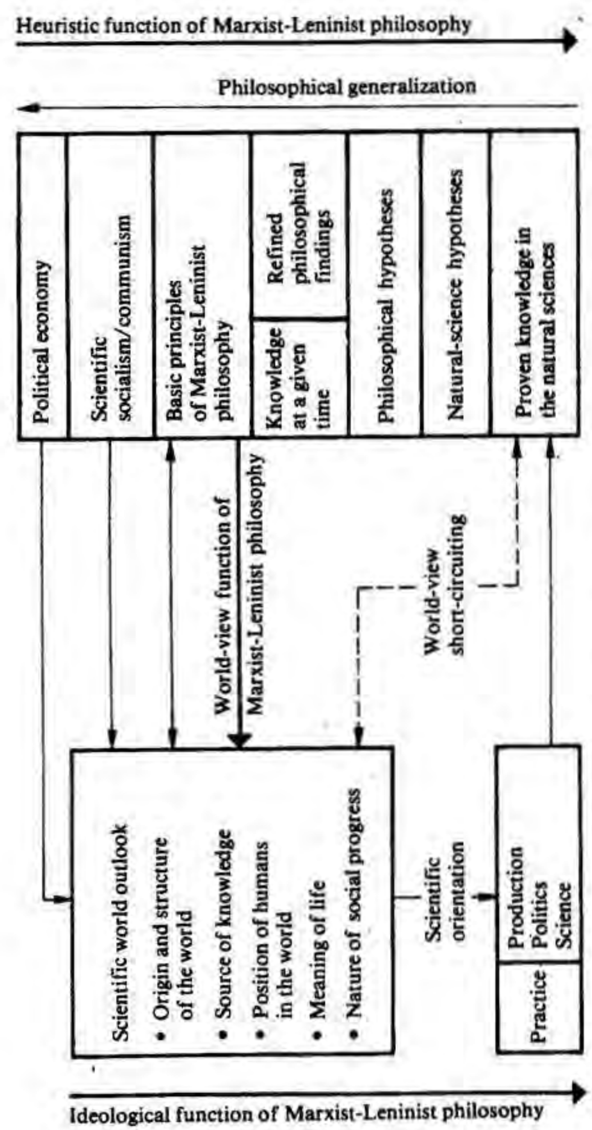
We have now described three different degrees of generalization of philosophical knowledge. The basic philosophical principles formulated by Marx, Engels, and Lenin represent the greatest degree of generalization and have the largest overall truth content. The totality of human practice has confirmed that they provide satisfactory answers to the major questions of world outlook. These basic principles are formulated to deal with the specific tasks connected with the state of knowledge at a given time. This is what Lenin means when he writes: "Hence, a revision of the 'form' of Engels' materialism, a revision of his natural-philosophical propositions is not only not 'revisionism,' in the accepted meaning of the term, but, on the contrary, is an essential requirement of Marxism."[18] Engels had stated that with each epoch-making discovery in the natural sciences, materialism would have to change its form.[19] This has occasionally been misunderstood to mean that the philosophical basis for classical physics is mechanical materialism, while modern physics needs dialectical materialism. We are convinced that dialectical materialism is the philosophical basis for the whole of physics, including classical physics.[20]

Philosophical hypotheses are philosophical findings of the lowest degree of generalization and truth. They are closest to the *natural-science hypotheses*, and it is often difficult to separate them precisely. Unlike natural-science hypotheses, they are not compelling consequences of a scientific discovery and therefore always exist as a field of possible hypotheses. If they are recognized as unfounded, this does not deny the validity of the scientific world outlook, because the latter demands that we see phenomena in their own real connections and not in some nonexistent fantastic connection.

It is neither surprising nor disturbing that philosophical hypotheses are often difficult to distinguish from natural-science hypotheses. In areas in which the hypotheses of philosophy and of natural science come into closest contact, the aim cannot be to find an exact dividing line between philosophy and natural science. The emphasis must be on a better understanding of the actual connection.

The formulation of philosophical hypotheses that can help develop science demands not only a creative imagination, but, above all, a well-founded knowledge both of the particular scientific field and of philosophy (including its history). This task certainly cannot be the aim of all work done on philosophical problems connected with the development of science. However, if the necessity of establishing philosophical principles for the formulation of philosophical hypotheses for a given level of scientific development is denied, then philosophy is in danger of continually lagging behind the rapidly developing sciences. It would then certainly not be justified to consider Marxist-Leninist philosophy as an epistemological, methodological, and general philosophical foundation for the development of science.

The need to think more about epistemological and methodological questions within the framework of the heuristic function must not, however, lead us to neglect the function of philosophy to provide a world view, because such neglect would put us in a positivist position. In the epistemological process in the natural sciences, Marxist-Leninist philosophy must fulfill its role as a world view and serve as an ideological guide to provide a direction for scientific development in the interests of society. Only on this basis can the heuristic function of philosophy in the epistemological process in the natural sciences be developed.



Functions of Marxist-Leninist philosophy and links between world view and social practice.

Since this complicated connection between the basic philosophical principles and the natural sciences is analogous to the connection between philosophical principles and the social sciences, and since it also applies to generalized social and individual experience, a similarly complicated picture results for the ideological function of Marxist-Leninist philosophy in the totality of social practice. Here we have links that need further research.

The functions of philosophy and the links between the scientific world view of the working class and social practice are represented in the diagram. The diagram makes clear the connections between the natural sciences and Marxist-Leninist philosophy. The necessary separation of interconnected phenomena within the diagram must not be absolutized. In the investigation of concrete questions, to which we will now turn on the basis of the conception described above, we must always keep in mind *the necessary unity of ideology, heuristic function, and world view*, in which the world view plays the dominating role. This diagram displays a number of important features of our conception.

a. Division of labor and cooperation between philosophers and natural scientists

For their scientific work, as well as for their activities as members of a society, natural scientists need a scientific world view. The range of scientific work extends from well-established scientific knowledge to philosophical hypotheses. The exploration of philosophical problems in the natural sciences requires specialists with a well-rounded knowledge of philosophy and natural science. The scope of their scientific work extends from the basic principles of philosophy through the philosophical hypotheses which can be transformed into natural-science hypotheses. The overlapping fields can be extended on both sides, but then the philosopher no longer works as a philosopher and the natural scientist no longer as a natural scientist. This means that for research in natural science philosophers cannot simply rely on the truth of their scientific world view, nor can the natural scientist simply transfer the methods that are successful in the natural sciences to philosophical research. In the collaboration between philosophers and the natural scientists, it is not necessary to extend the range of scientific work of each; philosophy and natural science can mutually develop in close interaction on an equal basis.

b. Assessment of philosophical views among natural scientists and philosophical "evaluation" of theories of natural science

A world view cannot be formed directly from knowledge of natural science, nor can the laws of nature be deduced directly from a world view. Without an analysis of the corresponding links, one can neither assess the validity of theories in the natural sciences on the basis of the philosophical explanations and reflections of the natural scientists, nor must a valid theory in the natural sciences inevitably lead the natural scientist to a dialectical-materialist world view. A differentiated assessment of the philosophical views of natural scientists demands not only the analysis of their explicit philosophical statements (often written in the form of a popular scientific work or as a foreword to a book), but also an analysis of their scientific approach and the explicit or implicit philosophical views on which this approach is based.[21] Little is to be gained by appending an "-ism" to the work of a natural scientist. Such labeling can be useful in ideological struggles between world views, since there the battle lines must remain clear. However, when one tries to clarify the relationship between philosophical views and the epistemological process in natural science, such labeling is more a hindrance than a help.

c. Unity of functions in Marxist-Leninist philosophy

Along with the continuing progress in natural science, Marxist-Leninist philosophy must develop in such a way that it continues to carry out its various functions within the natural sciences. Occasionally one comes across the view that its heuristic function should be abandoned because of the negative consequences in the past that resulted from too narrow a conception of its functions as a world view and ideology. It is unfortunate that, in the past, incorrect theories in the natural sciences were accepted and correct ones rejected because it was claimed that the latter were based on wrong philosophical and ideological premises, while the former were allegedly philosophically and ideologically sound. Today it is important to analyze this history in order to ensure a constructive approach to the interconnection between Marxist-Leninist philosophy and the natural sciences and thus to contribute to a deepening of this world view. We would be throwing out the baby with the bath if we denied the possibility of using philosophy heuristically for the development of science.

At the same time, however, one must warn against overestimating the achievements. While we have had a number of impressive results in the philosophical generalization of developments in natural science and have a clearer understanding of the implications of world view and ideology to the development of science, we are still very much lagging in the development of this heuristic function. Understandably enough, Marx, Engels, and Lenin dealt only a little with this aspect of the dialectical- and historical-materialist world view. Their aim was to establish the world view of the revolutionary working class on firm theoretical foundations, and for this the further development of the natural sciences played only a subordinate role. The material gathered by the natural sciences at the time was sufficient to substantiate the basic philosophical principles. This does not mean, however, that the natural sciences can be ignored. Further research must be carried out to develop more fully the heuristic potential of Marxist-Leninist philosophy for research in the natural sciences, and this potential must be utilized to provide an orientation to science to serve the interests of society and to solve the ethical and moral problems faced by natural scientists.[22]

Chapter Two
MATERIALISM AND STRUCTURE

After the general description of the relationship between Marxist-Leninist philosophy and the natural sciences given in chapter 1, we will now investigate some important questions arising from this relationship, particularly in the physical sciences.

1. Matter or Substance?

Consistent materialism is the decisive philosophical principle for physics as for all other fields. The recognition that matter is primary in relation to consciousness forms the philosophical foundation of the dialectical- and historical-materialist solution of all epistemological, ontological, and methodological problems. A philosophical analysis of the history of physics shows that it is precisely that science which has been largely responsible for the development of a consistent materialism.

The speculative attempts of Greek Atomists like Leucippus, Democritus, and Epicurus to create a materialism lie outside of physics, at least by our present-day standards. Like their predecessors, Thales, Anaximander, Anaximenes, Heraclitus, and others, they assumed that the world can be explained out of itself and not in terms of idealist principles. In line with their conviction that the many forms of phenomena must be reduced to their most simpl parts, the ancient Atomists postulated that all material objects cor sisted of indivisible particles. This was an important methodolo ical theory, which was of great significance for the emergence c physics. What is important for us today is not so much their vie of the atoms themselves, but their assumption that observable ol jects consist of parts and that an analysis of the behavior of thes parts can lead to knowledge about the object as a whole. It wa among the Greek Atomists that the idea was born that a single ph nomenon could be taken out of the totality of objective reality an examined in relative isolation, and the knowledge thus gained er ables us to understand the phenomenon in objective interconne tion with other phenomena.

It is certainly not correct to consider atomism the theoretic starting point of materialism. Materialism is by no means tied t atomism; also, the view that there are no ultimately indivisible ol jects is fully compatible with a materialist position. However, hi torically, ancient atomism was a valuable world view and a phi osophical basis for developing a consistent materialism. It had direct heuristic influence on the scientific research associated wit the chemical atomism of the nineteenth century (Dalton, Be zelius, and others). The epistemological and methodological posi tions of the ancient Atomists were heuristically fruitful for the de velopment of classical mechanics, through the work of Copernicus Galileo, Kepler, Newton, and others, which finally led to the emer gence of physics as an independent science.

Physics could develop only under the philosophical assumptio that one could analytically isolate continually changing objects phenomena, and processes from their universal interconnectio and that the laws discovered for these isolated objects also des cribed what, under definite conditions, could be general, necessar and essential relations for the corresponding objects in the totalit of their interconnections. The simplest assumption about the iso lated objects is to see them as unchangeable, although Heraclitu already knew that, strictly speaking, there is nothing that is no subject to change. Classical mechanics showed that appropriat idealizations of a large group of material objects is possible. It wa the development of thermodynamics, electrodynamics, and, abov all, the theory of relativity and quantum mechanics which mad clear the limits of the idealizations assumed in classical mechanics Today we know that the displacement of macrobodies moving a speeds considerably less than that of light is correctly reflected b classical mechanics. From this we know that the physical proper

ties of the objects investigated by classical mechanics, such as weight, inertia, impenetrability, and corporeality, do not by any means apply to all material objects. Therefore, we have no difficulty today in rejecting all attempts to define philosophically the concept of matter in terms of the physical properties of the material bodies of mechanics. But this does not change the fact that the laws of motion of classical mechanics reflect the objective reality. The natural scientists who were responsible for the development and elaboration of this theory knew very well that classical mechanics is able to represent with sufficient accuracy the mechanical motion that takes place outside and independently of human consciousness. Their findings give them sufficient reason to adopt a spontaneously materialist attitude.

If they were also religious, as was the case for many of them, it affected their work only insofar as they were unable to cope with unsolved problems of their field. For example, Newton introduced the Creator to give the planets the first impulse and to carry out the corrections necessary to prevent the solar system from collapsing. With due respect to Newton's scientific achievements, Engels writes in connection with the later attempts by scientists to postulate a first impulse from outside: "Copernicus, at the beginning of the period, shows theology the door; Newton closes the period with the postulate of a divine first impulse."[1]

Nevertheless, classical mechanics contributed much to an understanding of philosophical materialism. One example is the realization that there is no difference in natural science between the motion of "heavenly" and "earthly" bodies. Both move in accordance with Newton's laws of motion, which became the physical and mathematical basis for the Copernican system. In the seventeenth and eighteenth centuries this first theory of natural science played an important role in the struggle between philosophical materialism and idealism.

As long as classical mechanics remained the only successful scientific theory, false conclusions inevitably arose from its philosophical generalization. Seen from the vantage point of the present day, it is quite understandable that the very success of this scientific theory gave rise to the danger of its becoming a philosophical principle and thereby being elevated to a level of considerably greater generality than was justified. It was in the French enlightenment of the seventeenth and eighteenth centuries that philosophical materialism was given a largely mechanistic interpretation. The philosophical concept of matter was defined through the mechanical properties of macroobjects, and a number of attempts were made to transfer the laws of classical mechanics to the analysis of social development. The principal characteristics of mechanical materialism (matter is a substance with mechanical properties; all motion is reduced to change of place; law and causality are identical; everything happens with absolute necessity; chance exists only at the intersection of two or more causal chains, etc.) are understandable today as the logical consequence of the history of this philosophical school and the level of scientific knowledge at the time. There is, however, no reason to state that mechanical materialism is the inevitable consequence of classical mechanics, let alone that it was the philosophical basis for its development. In fact, mechanical materialism was historically the result of an unjustified philosophical generalization of classical mechanics. Today one can show[2] that such an important part of mechanical materialism as Laplacian determinism does not even itself, strictly speaking, conform with classical mechanics. Yet, it is necessary to assess properly the merits of this philosophy. Engels writes on this: "It is to the highest credit of the philosophy of the time that it did not let itself be led astray by the restricted state of contemporary natural knowledge, and that — from Spinoza down to the great French materialists — it insisted on explaining the world from the world itself and left the justification in detail to the natural sciences of the future."[3]

Marx and Engels criticized mechanical materialism and its concept of matter at a time when its limitations for physics were by no means obvious. The foundations of their philosophical criticism were Hegel's dialectics, materialistically interpreted, and the findings of a number of other sciences, including their own historical materialism and political economy.

The development of thermodynamics in physics first pointed to the narrowness of the mechanical-materialist concept of matter. However, the fact that the laws of thermodynamics could not be fully reduced to classical mechanics could have been interpreted as a purely technical difficulty which would not necessarily have caused scientists, on the basis of the state of knowledge during the second half of the nineteenth century, to revise the mechanical-materialist concept of matter. The development of electrodynamics led to more serious difficulties. In Newtonian mechanics the motion of point masses was the object of investigation. In Maxwell's equations, however, the fields appeared as the independent objects of physical theory. After it became clear that the Maxwell field equations had solutions that represented the propagation of electromagnetic waves and once the existence of these waves was

established experimentally, it was necessary, under the mechanical-materialist concept of matter, to search for a material carrier of these waves. This carrier, which was called the *ether*, had to have mechanical properties. The enormous difficulties presented by the ether theory were removed in 1905 as a result of the abandonment of the ether by Einstein, and it was proved, further, that physical fields have an objectively real existence and cannot be identified with material stuff. Only two philosophical alternatives then remained. One was to change the now too-narrow concept of matter so as to embrace both stuff and fields. The second was to hold fast to the earlier concept of matter and give up philosophical materialism in favor of idealism. Both paths were taken by physicists and the corresponding schools were developed to accommodate the two approaches.

The proclamation of idealism led to many epistemological and methodological difficulties. Idealism could be maintained only with the aid of increasingly complicated philosophical constructions, which had to be devised so as not to impede progress in physical research. Very often, however, this did not succeed. For example, Poincaré's ideas on conventionalism prevented him from developing the special theory of relativity. Mach, despite his well-founded criticism of mechanistic positions, was unable, because of his subjective-idealist approach, to assess the significance of new fundamental physical ideas at two important points. He rejected the atom, because he accepted only the existence of things which he could directly and sensuously perceive — and atoms were not perceptible. He was initially enthusiastic about the special theory of relativity, but he became a strong opponent of relativistic physics after the general theory of relativity was developed and dissociated himself from this school completely. However, from the examples given, one cannot conclude that physicists who take idealist positions automatically become incapable of making new discoveries in physics. This can be seen, for example, from the work of Heisenberg and Jordan on the development of quantum mechanics. An analysis of each individual case reveals, however, that it is not the explicitly formulated idealist position, but an implicitly assumed materialism that constitutes the philosophical basis for new discoveries in natural science.

The "crisis in physics" at the turn of the century led both to attempts to give up materialism and to attempts to change the philosophical concept of matter without abandoning the materialist standpoint. Here, too, complicated physical and philosophical questions had to be answered: Which physical knowledge could be regarded as sufficiently well established that it could serve as the new physical basis for the philosophical definition of matter, but at the same time guarantee that further progress would not again lead to a situation in which one would either have to give up materialism or change the definition of matter? Which physical knowledge could encompass such general properties of objective reality that it could become a basic philosophical concept for a world view that would embrace nature, society, and thought?

While the philosophically oriented physicists devoted much attention to the first question at the beginning of the twentieth century, hardly anyone considered the second question. The majority either strictly separated the "exact natural sciences" from the "descriptive social and mental sciences" or were firmly convinced that all science could be reduced to physics and mathematics. Both attitudes were and still are represented in bourgeois ideology. For the first group this second question appears pointless, and for the other group the question seems to have a relatively simple answer.

The situation at the turn of the century, especially after the development of the special theory of relativity, was a decisive one for the "crisis of physics." The discovery of X-rays, the electron, and natural radioactivity, the introduction of Planck's quantum of action, and special relativity theory created considerable difficulties for mechanical materialism and its conception of substance, in accordance with which things and their properties and relations are regarded in a metaphysical* and absolute way. The X-rays did not fit into the mechanistic view of the impenetrability of material objects. Radioactivity showed that even the simplest objects are by no means as immutable as mechanistic materialism had assumed. The quantization of physical quantities did not fit into a physical world view which assumed that nature did not take jumps. One philosophical school among the physicists of that time concluded from these and other difficulties that one had to give up materialism and find a theoretical justification of idealism based on natural science. Another philosophical school of physicists tried to rescue the old materialist positions at all cost because only these positions appeared to be in harmony with the physical knowledge acquired up to that time.

These fundamental conflicts among world views were necessarily part of the development of physics at the beginning of our century,

*Here the term *metaphysical* denotes *having an unchanging essence.*

but they went far beyond physics. After the defeat of the 1905 revolution in Russia, a strong group of theoreticians in working-class movements inside Russia and abroad were using the philosophical discussions in physics to undermine the materialist foundations on which the theoretical positions of these movements were based. Lenin thus found it necessary to make a profound study of the philosophical controversies around physics, the results of which were published in his book, *Materialism and Empirio-criticism*, in 1908.

Through his philosophical analysis of the state of physical knowledge at that time, Lenin concluded that the mechanical-materialist concept of matter had reached its limits. He pointed out that this did not mean that materialism had failed, but that one now needed to take seriously Marx and Engels' critique of mechanical materialism. The way out of the "crisis of physics" philosophically was not to adopt idealism, but to replace outdated mechanistic views with conscious materialist thinking. Lenin recognized more clearly than the physicists engaged in the conflict of world views that any new concept of matter formulated from within physics would sooner or later have to lead to serious problems of an epistemological and methodological nature connected with a world view. That is why his *philosophical* solution, a continuation of the work of Marx and Engels, avoided defining the concept of matter within the framework of natural science. Since then, the concept of matter in Marxist-Leninist philosophy has been reflexively established as a basic philosophical concept: matter is defined by its relationship to consciousness and consciousness, as a philosophical concept, is defined through its relationship to matter. Only within the framework of what Engels called the great basic question of philosophy, that is, the relation of thinking and being, is a counterposing of matter and consciousness absolute. *Lenin defines the concept of matter as "a philosophical category denoting the objective reality which is given to man by his sensations, and which is copied, photographed and reflected by our sensations, while existing independently of them."*[4]

This philosophical definition, in contrast to the mechanical-materialist concept of matter, is not bound to specific physical properties of material objects. Matter is not identified with substance. The "*sole* 'property' of matter with whose recognition philosophical materialism is bound up is the property of *being an objective reality*, of existing outside the mind."[5] The view of matter as substance, however, postulates the existence of an ultimate carrier of all properties and determinations of matter.

Atomism was an example of this. The atoms were considered the carriers of all properties and determinations, and it was thought that the qualitative variedness of phenomena could be reduced to quantitative relations. Another example of the view of substance is to equate matter with stuff or field. A certain carrier or group of carriers is always assumed. This substance remains even when the properties and determinations change or disappear. Thus the substance view asserts the existence of carriers of properties and relations of material phenomena and objects, these carriers continuing to exist even when the properties are gone.

Developments in physics brought to light a number of decisive arguments against this view of matter. If such substance existed, then every property that we find in physics must either be due to it or not be due to it. In quantum mechanics, however, it is clear, for example, that some properties of microobjects are not due to a substance, but are the result of objective interactions (see chapter 3). The wave-particle duality prevents us from viewing stuff and fields as substance. A concept of matter which sees field and particle as a unitary substance could not function as a fundamental philosophical principle.

In *Materialism and Empirio-criticism* Lenin dealt in detail with the relation between the concept of matter and the structure of matter, and he refuted the idealist attacks on dialectical materialism's fundamental position. In doing so, he developed ideas of far-reaching significance. According to Lenin, the relativity of our knowledge about the structure of matter does not contradict the acceptance of an objective reality, while the philosophical view of structure provides an orientation for further scientific research. Lenin objected to the assumption of eternal, unchangeable substances and emphasized the inexhaustibility of matter in its content. Since Lenin's time many philosophical discussions and important discoveries in the natural sciences have shed new light on these views. On the physical side there is progress, for example, in high-energy physics, which provides new ways of dealing with the question of ultimate building blocks of matter, a question which has a very important role in the history of philosophy. Demands are being made on all sciences to solve methodological problems linked with structural investigations. However, philosophical structuralism, particularly in France, led to a one-sided approach to science — to the neglect of the diachronic as compared to synchronic, the the historical as compared to the logical, and the human being as compared to the structure.

2. Lenin's Concept of Matter and the Structure of Matter

Lenin made a distinction between philosophical questions about the source of our knowledge and about the structure of matter. The source of our knowledge exists outside and independently of our mind and can be studied by it. This is precisely the content of Lenin's concept of matter.

In the concept of matter, however, nothing is stated about *how* consciousness exists outside and independently of the mind. From the investigations into structure carried out in the sciences, which provide statements about the general relations and laws of objective reality, we draw our own philosophical conclusions. It is from the results of science itself that we obtain evidence for the philosophical thesis that matter is infinite in content and that there can be no final absolute truth about the structure of matter. Every concrete level of knowledge, be it about physical, biological, or social objects, reveals different relations in the different sciences. Their essence can be known only through a large number of phenomena in which some aspect of the essence is always conserved. Therefore, science searches for general, necessary (i.e., reproducible), and essential connections, in other words, connections which determine the character of the phenomenon. These are the objective laws. So it is not the "thing-in-itself" that is known, but each object is investigated within its interrelationships, whereby different relations can lead to different laws. That is why the question of whether we should concentrate our scientific investigations on things or structures is already tied to the philosophical approach to structure within the methodology of science.

It was Lenin's aim, like that of Feuerbach and Engels, to turn Kant's unknowable "thing-in-itself" into a knowable "thing-for-us." In the dispute around this subject, the relationship between structure and element did not yet play a special role. Lenin had to counter the view of Mach which denied the existence of something outside and independent of our consciousness, or which denied even the possibility of such an existence. In comparison, even Kant's views were progressive, as Lenin stressed. But Lenin differentiated between Kant's and Feuerbach's "in-itself" and commented that Feuerbach "rebukes Kant because for the latter the 'thing-in-itself' is an 'abstraction without reality'. For Feuerbach the 'thing-in-itself' is an 'abstraction *with* reality', that is, a world existing outside us, completely knowable and fundamentally not different from 'appearance'."[6]

As soon as objects change and are subjected to study, the problem is to find those relations which are valid for the objects but have not yet appeared in the process of cognition. That is why we do not describe a falling stone when teaching physics, but explain the law of free fall, which makes it possible for us to determine the behavior of freely falling bodies. This does not mean, however, that the reality recognized is the whole of reality. The materialist viewpoint demands that in the process of cognition we accept potential objects about whose structure we know nothing. Although we can derive the laws of the potential objects from the laws of the existing objects, we can do this only within a framework that establishes the conditions for the existence of the laws. In this connection, Lenin noted that the progress made by science at the beginning of our century led some natural scientists to state: "Matter has disappeared." This idealist view has been encountered repeatedly in the past, for example, in connection with the discovery of antiparticles, and we meet it even today. However, it has lost much of its force as an argument against materialism because Lenin's definition of matter is much better known today than at the beginning of the century. Already at that time, Lenin drew attention to the epistemological kernel of the statement: "matter disappears," namely, that "the limit within which we have hitherto known matter disappears and that our knowledge is penetrating deeper; properties of matter are likewise disappearing which formerly seemed absolute, immutable and primary (impenetrability, inertia, mass, etc.) and which are now revealed to be relative and characteristic only of certain states of matter. For the *sole* 'property' of matter with whose recognition philosophical materialism is bound up is the property of *being an objective reality*, of existing outside the mind."[7]

Lenin rejected equating materialism with mechanistic, metaphysical materialism, which had declared the hitherto known relations to be the only existing real relations, and thus took the concept for the reality. Only dialectical materialism was able to clarify scientifically the relation between the relativity of our cognition and the recognition of objective reality by replacing the physical concept of matter with a philosophical one. So the question of *whether* something exists outside and independently of our consciousness must be separated from the question of *how* it exists and *what* its structure must be. To the latter question Lenin answers: "Dialectical materialism insists on the approximate, relative character of every scientific theory of the structure of matter and its properties."[8]

Dialectical materialism encourages the investigation of new

structures, the discovery of hitherto unknown objects. Materialism demands recognition of facts and not their subordination to hitherto valid statements and principles about the structure of matter. Every new insight can only confirm the existence of something that is outside and independent of, and recognized by, the mind. It also points, in the epistemological process, to further unknown potential objects whose structure can be investigated. In contrast to objective idealism, dialectical materialism stresses the knowability of all objects and processes by means of the dialectical-materialist theory of reflection, and, in contrast to subjective idealism, it postulates the existence of known, as well as unknown, objects and processes outside and independent of our mind. No "ontological addition" to Lenin's concept of matter is necessary, because knowability presupposes effects on the sense organs, while changes in the objects are the basis of knowledge. This becomes very clear in Lenin's critique of Kant's agnosticism. A materialist must not stop at merely acknowledging the existence of objects outside and independent of our mind, but must also explain how we derive our knowledge from this objective source. Our knowledge is a reflection of objective reality, which we perceive through the organization of sensuous phenomena with the aid of our empirical and theoretical knowledge. That is why, for Lenin, too, recognition of objective truth is fundamental to dialectical materialism.

An "ontological addition" would be a step backward in philosophical thinking to the position of pre-Marxist materialism, when matter was tied to certain discernible structural properties of material objects. This was precisely the view that Lenin proved to be incorrect. One cannot accept the thesis that there is no absolute truth regarding the structure of matter and then demand an ontological determination of the concept of matter which can be nothing more than a statement about some definite physical structure or other definite structure associated with a particular science. This would bind materialism, as a fundamental philosophical principle, to the state of knowledge of individual sciences of a certain period. The concept of matter defined by contrasting it with consciousness — whereby consciousness, narrowed epistemologically, signifies only a product of the development of matter and a property of matter, as well as the specific human form of reflection (the result of it) — is valid as long as humans act as conscious beings capable of cognition. Only the results of the process of cognition in the form of concepts, statements, and theories are counterposed to the material objects and processes in order to give the materialist answer to the basic question of philosophy, namely, that matter is primary to the mind. Insofar as one is dealing with philosophical questions which do not touch upon this primacy, we go beyond this counterposition and investigate, let us say, the relationship of the subject of cognition, as a unity of material and mental processes, to the object of cognition, which can have a material or ideal character or both. And here, according to Lenin, we have reached the field of structural investigations for which the individual sciences deliver new insights that must be analyzed by the philosophers. For materialists there can be no a priori statements of philosophy, but only the philosophical analysis of the material provided by the individual sciences, which helps us elaborate philosophical theses and set up philosophical hypotheses.

The present-day significance of Lenin's conceptions is thus the following:

First, in contemporary discussions on philosophical problems of the sciences, the two questions posed by Lenin have to be considered. In the confrontation with idealism the question that is important is what is the source of our knowledge, and this embraces the relation of human beings to their environment. This question must be separated from that regarding the structure of matter, new answers to which are continually being provided by research in all scientific fields.

Second, Lenin gave a clear answer to the first question through his definition of matter and his proof that the relativity (i.e., the incomplete and approximate character) of our knowledge of the structure of matter in no way contradicts the recognition of the existence of objective reality. The acceptance of objective truth does not exclude the dialectic between relative and absolute truth, but demands rejection of final absolute truths about the structure of matter.

Third, every direction of scientific research, insofar as it has the structure of matter as its basis, must be continually reexamined to ensure that it does not go beyond a materialist approach. When it was shown, for example, that the ether hypothesis was not necessary to explain physical phenomena, the scientific orientation on which the search for ether was based had to be dropped. It is in this sense that a materialist orientation in the sciences must be developed on the basis of the results of research in the individual sciences.

Fourth, in connection with the growing significance of methodological problems arising out of structural investigations, the philosophical understanding of the concept of structure should be further developed.

3. *What Is Structure?*

Starting from the usual definition of *system* in mathematics and logic as a set of elements together with a set of relations among these elements, and of *structure* as a set of relations, in philosophical literature structure is often described as the invariant aspect of a system. This takes into account an essential aspect of this concept, although it is then, in fact, identified with the concept of law. Our definition, however, of the *structure of a system* is: *the totality of the essential and inessential, general and particular, necessary and contingent relations among the elements of a system during a certain period of time*. The behavior of a system depends on the elements and their structure as well as on the structure of the system. The essential behavior of a system, however, is determined by the totality of the laws governing the system.

Laws exist on the basis of a complex of causal relations which must obviously have a certain structure, because recognition of objective, relatively stable systems is a requisite for cognition. Thus, the dialectical unity of conditionedness (transient relations) and determinateness (relations in some definite time interval) or of causality and structure is the basis of cognition. A thought experiment which recognizes only universal interaction would not lead us to the knowledge of any object, because knowledge of the whole universe would be necessary for cognition. That is why we are not interested in the universal conditionedness at all times, but the conditionedness of the elements of a system during a certain time period and their determinateness. In this way we abstract from the structure of the elements and their external effects when we wish to acquire knowledge of the laws of the system. Furthermore, in the structure of the system we search for the general, necessary and essential relations. Therefore, *the basis for the existence of laws is the causally conditioned and structurally determined motion of the elements in a system*. Thus one must investigate, as an important dialectical factor, the relations between causality and structure.

If the concept of law stresses general, necessary and essential relations in the concrete mediation of the connections in causality, then this is possible because this mediation has an inner structure. The discussion in modern physics around the concepts of "place" and "coordinate," of elementary lengths and structure of elementary particles shows us that in physical theory, too, the structure of material objects must be taken into account. If one identifies structure with law, then this determinateness in the causal conditionedness within the single object can no longer be seen, but is reduced to the essential structure.

If mathematics and logic view structure undifferentiatedly as the totality of relations among the elements of a system, then the philosophical content cannot consist only in designating the essential relations by means of this concept of structure without indicating which concept embraces the totality of the other relations. The philosophical solution must make clear the significance of the differentiation of all relations into general and particular, necessary and contingent, essential and inessential, to give direction to a dialectical analysis and also to reveal the features that distinguish them. In this way, the content of this concept is preserved and not narrowed down. If we now turn to the concept of the *structure of matter* as used by Lenin, we can then define it as *the totality of relations of material objects among themselves*. Every concrete characteristic of material objects is subject to research in some particular scientific field. Statements about it must be tested in practice. General statements on structure derived by philosophy from the findings of the individual sciences must also be tested in the individual sciences in a complicated process of cognition involving the elaboration of philosophical statements and formulation of philosophical hypotheses. Such general statements also relate to the totality of relations that material objects have to one another, relations which can be general and particular, necessary and contingent, possible and actual, etc.

The development of science continually brings forth new philosophical structural problems. The necessary philosophical analysis of the new statements on structure must be tied to a defense of the materialist viewpoint. Interesting in this connection is Lenin's view of space and time:

> In his *Mechanics*, Mach defends the mathematicians who are investigating the problem of conceivable spaces with *n* dimensions; he defends them against the charge of drawing "preposterous" conclusions from their investigations. . . . For the materialists, by recognizing the real world, the matter we perceive, as an *objective* reality, have the right to conclude from this that all human concepts, whatever their purpose, that go beyond the bounds of time and space are *unreal*.[9]

Here, too, the issue is the materialist approach to space and time on the one hand, and knowledge about space-time structures derived from the individual sciences on the other. Lenin gives his opinion on the former. This becomes clear in his criticism of Bazarov who "erred in confusing the mutability of human conceptions of time and space, their exclusively relative character, with the immutability of the fact that man and nature exist only in time and space."[10] In this philosophical question the issue is obviously not that of a statement on the objective space-time structures, for these, too, are subject to philosophical analysis. For Lenin it is clear that when we speak about objective space and mathematical space, we are talking about two different concepts of space. However, the development of the sciences shows that one is not independent of the other. The theory of relativity proved the unity of matter, motion, space, and time. Moving material objects have, in their conditionedness, a space-time structure characterized by material processes taking place alongside and after one another. A universal world time and an absolute space do not exist.

In functional analysis one understands abstract space to be a set of elements within which a limiting process can be considered. For some definite space, certain operations like addition, multiplication, etc., are defined for certain elements. Since objective space, or rather, objective space-time, is not a material object existing alongside others, but is a definite relationship among material objects, the recognition of objective reality at the same time means recognition of the objectivity of space and time. It must be possible to verify space-time theories with the material objects. This applies to relativity theory as well as to other space-time theories. Such is the materialist approach on this matter to the basic question of philosophy: the relation of thinking and being.

Some of Lenin's statements about the structure of space-time are, of course, based on our knowledge at the turn of the century and reflect the development of philosophical knowledge at that time. This was characteristic of his approach. He took what was then considered to be well-established scientific knowledge and generalized it philosophically on the basis of fundamental principles. Much more important, however, is his basic approach, which was to recognize the existence of objective space-time structures. Today one can express Lenin's arguments more precisely if one looks upon the thesis that space and time are forms of existence of matter as an expression of the view that the space-time theories in the individual scientific fields are reflections of the objective space-time structures of material objects and systems. Lenin's philosophical statement should not be understood as an opinion on the structure of space-time, but as a basic materialist viewpoint linked to the dialectical-materialist concept of the material unity of the world.

Lenin's comments on the inexhaustibility of matter* and his rejection of absolute substances are of great importance for the investigation of space-time structures. As objective space appears to be a part of the structure of material systems, one can also ask whether spatial relations can always be considered to be absolutely independent of other relations. Obviously, this is no longer possible with regard to temporal relations, which fact also confirms Lenin's view that nothing is absolute. Not only spatial and temporal but also other relations will undoubtedly characterize more than before the behavior of material objects in our theories. While it was sufficient for mass-point mechanics to specify the space coordinates of point masses, elementary particle theory must take into account a large number of characteristics of objects by means of various quantum numbers. To see mathematical space generally as a series of relations is in line with the views given here, because it is a generalized view of space, wherein the structure of space is described by various operations. It is now much clearer than ever before that every philosophical analysis of physical knowledge must be based on the scientific nature of the materialist viewpoint, which stresses the primacy of matter over mind and thus also *the primacy of the objective structure over the theory of this structure*. Therefore, the structure of matter, as the totality of relations of material objects to one another, must be philosophically investigated on the basis of knowledge accumulated in the individual fields of science in order to determine the direction for further research.

Taking the structure of matter as the totality of relations among material objects, we can make a further conceptual differentiation which is already implied in the way philosophical language is used, although not always consciously. *All material objects studied by science can be classified according to their general properties and assigned to broad groups designated as types of matter.* In physics, these are *particles* and *antiparticles** as well as *fields*. That one type of matter can change into another, such as matter with and without rest mass, confirms the dialectical-materialist thesis about the unity of the world in its materiality. The types of matter are interconnected in their objective structure, motion, and development. It is these relations between the material objects which we describe as forms of matter and sometimes also as forms of existence of matter. The basic form in which matter exists is motion, which, in the classics of Marxism, is called the *mode of existence of matter*. The material motion forms the connection between the material objects and determines and conditions their inner structure and their place in the material system.

The structure of matter is thus the totality of relations between material objects, with account being taken of the dialectic of object and relations (which can change places in a concrete case) and the unity of the types and forms of matter. Here, the forms of matter are general relations among the objects, which are philosophically expressed in the categories motion, interconnection, development, and space-time. The concretization of the type and modes in which these forms of matter exist leads to the forms of motion, the forms of interconnection such as causality and law, and to the forms of development.

4. The Universality of Structures

If we base ourselves on Lenin's definition of matter and then ask in what way does Marxist-Leninist philosophy promote research in natural science, the answer can only be: the consequences arising from the materialist viewpoint must be consciously arrived at in a process in which the materials gathered from research in physics become the necessary foundation for the development of concepts

*"The 'essence' of things, or 'substance' is *also* relative; it expresses only the degree of profundity of man's knowledge of objects; and while yesterday the profundity of this knowledge did not go beyond the atom, and today does not go beyond the electron and ether, dialectical materialism insists on the temporary, relative, approximate character of all these *milestones* in the knowledge of nature gained by the progressing science of man. The electron is as *inexhaustible* as the atom, nature is infinite, but it infinitely *exists*." (Lenin, *Materialism and Empirio-criticism*, p. 262)

**Stoff* and *Antistoff* in the original German text. There is a certain linguistic ambiguity on this question. In English, the terms *matter* and *antimatter* are now often used in physics to denote either particles and antiparticles, respectively, or the more complex structures (e.g., nuclei and chemical elements) that may be formed from them, including corporeal (bodylike) forms, a concept which can be extended to include gases. In German, the terms *Stoff* and *Antistoff* correspond to this more general use of *matter* and *antimatter*. From the materialist viewpoint, however, fields are also forms of matter, so that the English terms *matter* and *antimatter* do not adequately distinguish particle or corporeal forms of matter from material fields, unlike the German term *Stoff*, which is not generally applied to fields. In the older natural-science literature in English one can encounter the term *stuff* used in the same sense as the German *Stoff*.

and hypotheses. With the help of the principle that all material objects have a structure, we will now show how to do this and use for an example some of the discussions that have taken place in elementary particle physics.

The recognition of the primacy of matter over consciousness is not only the presupposition for a scientific theory of knowledge, but also has further philosophical consequences. By accepting the primacy of matter and the knowability of material objects, one also acknowledges the existence of objective connections. If the objective connection is broken at any place, then knowability cannot be asserted. One can make the following thought experiment. In line with relativity theory, objective connection means that there is no material area which is not connected to other material areas through material processes, i.e., such connection produces effects which in principle must be perceivable by the sense organs and thus make knowledge possible. This can be a mediated (or indirect) effect, it need not be direct. Let us now imagine some region existing in complete isolation, i.e., without any connection to other regions. Such a region would be an unknowable thing-in-itself. If it has no effect on others, i.e., is not linked to other regions through material processes, the objective connection is broken at this place. This region is fundamentally unknowable because cognition assumes at least mediated effects on the sense organs.

Thus, the thesis that the world is, in principle, knowable is necessarily linked to the thesis about objective connections. Cognition, however, demands analysis, changes in reality, and emphasis on the essential aspects of an objective interaction. A requisite for cognition is the hierarchy of relations within the objective connection, its division into systems which are not absolutely isolated from one another because of the objective connection, but which can be separated in thought because of their relative stability. Only through this can we distinguish between inner and outer relations. Such systems, as relatively independent parts of an objective connection, can interact with other systems only if they have an inner structure which mediates the interaction. However, no decision can be made on whether these systems consist of indivisible building blocks. Here we are not looking at higher systems of matter, but only physical ones, and we ask whether ultimate building blocks of matter exist. The history of science tells us at this point, that we must first clarify what we mean by ultimate building block.

The mechanical-materialist view, which saw the point masses of classical mechanics as ultimate building blocks of matter defined only through spatial and temporal relations, quickly proved untenable. But elementary particle physics pointed to a new difficulty. In collisions between two particles at high energies, other particles emerge, and these can be considered as parts of the whole. But they are also "elementary" particles. The criterion normally used for parts and whole in spatial quantities fails here. Heisenberg writes

> Therefore, it is best to describe these collision processes not by claiming that the colliding particles have been destroyed, but by speaking of the emergence of new particles out of the collision energies in accordance with the laws of relativity theory. One can say that all particles are made of the same basic substance, which one can call energy or matter, or one can state: The basic substance "energy" becomes "matter" by taking on the form of an elementary particle. In this way, the new experiments taught us that the two apparently contradictory statements: "matter is infinitely divisible" and "we have the smallest units of matter" can be made compatible without getting into logical difficulties.[11]

According to Heisenberg, the field is the basic substance of physical processes. The particles are excitations of the field. By matter he understands here stuff or elementary particles. This leads us to the thought that Lenin's thesis on the inexhaustibility of matter can be made compatible with the assumption that there exist smallest units of matter. Inexhaustibility is no longer found in the variedness of physical objects, but in the relations among these objects. Then a finite number of ultimate particles would be inexhaustible in their relations.

But there are also other possibilities for a physical approach to the problem of elementary particles. For Heisenberg, the question of the structure of particles is unimportant, because it is subordinated to the question of the structure of the fundamental substance, but for other approaches, the problem of the structure of particles is an important one. Above all, the concept of divisibility needs to be clarified. The connection between the structure of particles and divisibility can be illustrated by recent developments in elementary particle physics. In 1964, Gell-Mann and Zweig proposed a set of fundamental particles as the building blocks of the elementary particles. These hypothetical particles, called *quarks*, have fractional electric charges. An intense search for these particles began, but at this writing there is no confirmed evidence for them. However, there are a number of indirect indications that this model is fruitful. For example, in 1968 Weinberg and Salam made a promising attempt to unite quantum electrodynamics with the theory of weak interactions. In the last few years several particles have been found whose existence supports the quark model and the work of Weinberg and Salam.* Investigations of the structure of strongly interacting particles also continues. The hypothesis that particles are pointlike (parton model) has again raised the question of the connection between structure of particles and divisibility.

It is obvious that structure cannot be defined solely in terms of its space-time relations. On the other hand, a new type of divisibility has been proposed. Quantum numbers which hitherto have been regarded indivisible are now thought to be divisible or, equivalently, new quantum numbers have been introduced (the *charmed quarks*). The divisibility of quantum numbers leads to hypothetical particles whose existence must be confirmed. The relationship of the structure of the elementary particles to the hypothetical particles now has to be clarified and the structure of the quarks investigated. The introduction of new quantum numbers makes the structure of particles even more complicated, so that even more quantities have to be used than before in order to describe them. The problem of structure arises on a still lower level if one thinks not only of spatial divisibility, but also of the divisibility of the quantum numbers. One can also assume a complicated structure for the same level, but nevertheless the problems will not disappear.

Here we see the connection between the philosophical thesis that systems have structure and elementary particle physics. Although philosophy cannot make any statements independently of the findings of the individual sciences, the general philosophical principles can have heuristic significance when linked with these findings.

From this position one can also consider some aspects of the philosophical orientation of science. As we have already seen, structural investigations into modern physics are no longer directed at the structure of an uninteresting object in its space-time relations, as was justifiably the case in mass-point mechanics. In its philosophical generalization, mechanical materialism concerned itself with the space-time relations of atoms, which resulted in complicated systems. It was denied that these systems have laws of their own, and thus each system was reduced to its elementary parts and relations, at least, in principle. This orientation led to the elements of the systems being treated as something primary. The

*Still more recently, encouraging support has come for the grand unification theories put forth in 1974. These theories unite the strong, electromagnetic, and weak interactions (but not gravitation) in one theoretical scheme.

body, the thing that belonged to the system, was the object of investigation. Even modern physics has now shown that statistics should be regarded not just as an aid for dealing with the behavior of many parameters, but as a science that formulates essential laws for the parameters of physical systems. This makes it clear that complicated and complex systems have laws of their own, which Marxist philosophy recognized long ago. These systems have not only an element structure, but also a system structure, on the basis of which system laws can be investigated. The investigation of structure in elementary particle physics is one part of the research on the structure of matter. The results already obtained from philosophical studies on the forms of matter based on research in the various sciences can be of heuristic value for solving philosophical problems in elementary particle physics.

The direction of scientific research which arises out of the philosophical principle that material systems possess structures does not lead simply to the investigation of individual objects and the neglect of the structure of the system, but to the determination of the place of the object as one element in the system, and the determination of the system structure in its essential aspects, and with it, the system laws. The role of the elements in determining the system character and the system laws must also be investigated. In this connection, further philosophical investigations must be conducted on questions such as divisibility, on the relation between symmetry and asymmetry, on the part and the whole, and so on. Every theory of the structure of material objects in material systems and of the integrated structure of the entire system embraces a number of levels and types of relationships.

5. *Stages of Cognition of Structure*

The stages of cognition of structure can be considered logically as well as historically. In the philosophical and scientific literature in which this has been done, comparisons are frequently made between modern science and the philosophy of ancient Greece and the Middle Ages. Such comparisons are based on analogies, and sometimes reference is made to the laws of development of thought, according to which the dialectical negation of synthetic views, through the investigation of a particular case, leads to a synthesis in the negation of the negation, which is not a return to the old, but includes the rational nucleus of an original view.

The following aspects of cognition of structure can be outlined:

First, there is the historically evolving view of material objects and processes, in the course of which their many-sidedness was dissolved in their space-time relations. The names of Copernicus, Galileo, Kepler, and Newton are associated with this development, according to which every structure is considered to be a space-time relation of qualitatively identical particles. In relation to the brilliant hypotheses of the Greek Atomists, this, too, represented important progress in knowledge, because it made it possible to comprehend structures and to investigate them further, as we can see from the achievements of classical physics. In the final analysis, however, it also limited the structure of matter to one type of matter only, that is, to the ultimate indivisible particle, and limited the forms of matter only to those relations among particles which were expressed in the laws of classical mechanics.

Second, the laws characteristic of particular objective systems must be taken into account. Engels pointed this out when he differentiated between the higher and the lower forms of motion and emphasized their relative independence along with their inner connection. Every system of structures has a place in the hierarchy of systems which exist beside one another and mutually interpenetrate each other, but which can also be positioned in this hierarchy as a particular general. This means that the essential system structures are dependent on one another, and the richness of relations among material objects becomes evident. Nature is infinitely complicated. New objects with new properties and new relations among the objects are continually being found. The forms of motion and development of matter range from physical to social movement, whereby the forms of matter in the various systems have their own specific natures. The area of our present concern, however, is the physical forms of motion.

Third, general theories emerge on the basis of the inner connection of the system structures and embrace the various fields through emphasis on their common structures. This also applies to the borderline areas among various sciences, such as the application of quantum theory to chemistry or the investigation of physical-chemical laws of biological evolution.

Fourth, general structural theories have been developed which make system-independent statements about structures much as mathematics uses mathematical theories. An example is cybernetical systems theory, but one can start even with the whole of mathematics, which deals with possible relations of well-defined systems. In this connection we can also mention the recent creation of a "structure theory" of mathematics with the aid of the theory of categories.

We see that cognition of structure has several aspects and stages. There are no straight and direct paths to structural cognition which lead deductively from the general theory of structure to a certain system structure or inductively from a system structure of general theories to structural theories.

6. *The Material Unity of the World and Unified Theories*

In the history of physics various attempts have been made to develop a unified theory of all physical objects and relations. In the eighteenth and nineteenth centuries, all phenomena were reduced to the mechanical relationship of identity of the smallest particles, so that the unity of the world was seen as the unity of mechanical relations, and the unified theory was simply classical mechanics. Frederick Engels examined the philosophical consequences of such a viewpoint and, on the basis of the scientific knowledge of the day, criticized the attempts to reduce all qualitative differences to quantitative relations. This criticism is interesting, both from the viewpoint of the theory of science and of philosophy. Historically, one can make an interesting comparison between Engels' criticism of the mechanical-materialist world view and the actual further development of science.

Engels objected to the view that one must reduce physiology, chemistry, etc., to mechanics, because this, he said, places impermissible limitations on the subject matter of nonmechanical sciences. He pointed to the connection between the sciences, to their continuity, as well as to the differentiation which does not allow simple reduction: "In physics, however, and still more in chemistry, not only does continual qualitative change take place in consequence of quantitative change, the transformation of quantity into quality, but there are also many qualitative changes to be taken into account whose dependence on quantitative change is by no means proven. That the present tendency of science goes in this direction can be readily granted, but does not prove that this direction is the exclusively correct one, that the pursuit of this tendency will *exhaust* the whole of physics and chemistry."[12]

As a dialectical materialist, Engels was a representative of materialist monism. He did not, however, try to fit the objective qualitative differences into a monistic world view, as did those natural scientists of the time who demanded the reduction of all systems and relations to the change of place of qualitatively identical smallest particles, all of which was to be described by means of the laws of classical mechanics. Engels did not follow the trend of the time, which was to reduce quality to quantity.. It was precisely those qualitative changes which could not be shown to be quantitatively conditioned that later led to the downfall of the mechanistic world view. One example is the already-mentioned attempt to understand the propagation of electromagnetic waves in the ether and the attempts to discover the nature of light. This was the starting point for relativity theory and quantum theory, which, in turn, served as starting points for the construction of an elementary particle theory.

Engels tried to grasp the principal trends in the development of science, but he could not, of course, foresee further developments in all their details. He did not live to see the discovery of radioactivity, the electron, and the theory of special relativity, nor did he know the results of the Michelson-Morley experiments, which (along with special relativity) established the nonexistence of the ether. In commenting on the scientific developments of his time, he criticized the strong belief of many natural scientists in the reducibility of all relations to mechanical ones. He summed up the consequences of the mechanical view of nature:

> It explains all change from change of place, all qualitative differences from quantitative ones, and overlooks that the relation of quality and quantity is reciprocal, that quality can become transformed into quantity just as much as quantity into quality, that, in fact, reciprocal action takes place. If all differences and changes of quality are to be reduced to quantitative differences and changes, to mechanical displacement, then we inevitably arrive at the proposition that all matter consists of *identical* smallest particles, and that all qualitative differences of the chemical elements of matter are caused by quantitative differences in number and by the spatial grouping of those smallest particles to form atoms. But we have not got so far yet.[13]

This consequence of the mechanistic approach to nature was not at all clear to many natural scientists, since they were not sufficiently interested in the philosophical analysis of their world view. The theory of the absolute qualitative identity of matter, as Engels correctly commented, could neither be empirically proved nor disproved. This is just as true today. Indeed, the attempts to find a unified theory of elementary particles no longer means rejecting

qualitative differences. The history of science has forced us to be more careful. There is, however, no doubt that some scientists still dream of one all-embracing world theory.

History proved Engels right in regard to mechanical materialism. It proved impossible to reduce all relations, even within physics, to mechanical ones. Here we need only point to the statistical interpretation of quantum mechanics and Heisenberg's indeterminacy relations, which clearly show the difference between the behavior of classical and quantum objects. This does not, however, completely negate the attempts to find a unified theory. First, there is no proof that some basic material substance, whose theoretical description would supply a unified theory of nature, does not, after all, exist. Second, attempts for unity in science always have a heuristic character. Even if we did not achieve a unified theory of nature, there have always been more general theories that described objects and relations which, up to then, had been seen in separation. Examples are Maxwell's theory and, later, the quantum theory. The latter did away with the absolute separation of waves and particles and brought them together to form a theory of physical objects.

The next major attempt to find a unified theory was the effort at the turn of this century to explain all properties of matter in terms of electromagnetic fields. The limitations of this viewpoint became clear even more quickly than the one-sidedness of mechanical materialism. Above all, the development of the quantum and relativity theories showed the limits of a unified electromagnetic theory of nature. While classical mechanics was a theory of forces acting between unchangeable particles, the introduction of the field concept, which played such an important role in electromagnetic theory, shattered the conception of unchangeable particles as the only physical objects. Not only the forces between particles were then investigated, but also the field relations and laws of a structural nature. Gravitation, and later the strong and weak interactions of elementary particles, could not, however, be reduced to the electromagnetic interaction. Physics produced new discoveries which showed that such a reduction was impossible. The significance of the field concept for the explanation of material processes led to the idea that one could build up a unified field theory of matter. Einstein and Infeld expanded upon such ideas:

> Could we not reject the concept of matter and build a pure field physics? What impresses our senses as matter is really a great concentration of energy into a comparatively small space. We

> could regard matter as the regions in space where the field is extremely strong. In this way a new philosophical background could be created. Its final aim would be the explanation of all events in nature by structure laws valid always and everywhere. A thrown stone is, from this point of view a changing field, where the states of greatest field intensity travel through space with the velocity of the stone. There would be no place, in our new physics, for both field and matter, field being the only reality. This new view is suggested by the great achievements of field physics, by our success in expressing the laws of electricity, magnetism, gravitation in the form of structure laws, and finally by the equivalence of mass and energy. Our ultimate problem would be to modify our field laws in such a way that they would not break down for regions in which the energy is enormously concentrated.[14]

That was the idea at the bottom of Einstein's efforts to find a unified field theory of matter. It eliminates the previous separation between the types of matter, *stuff* and *radiation*, an idea which later found firmer support through the transformation of stuff into radiation. While Einstein interpreted stuff as matter, for him *field* was an expression of structure and, in the final analysis, even an expression of the spatial conditions alone. This was the third attempt to develop a unified physical theory. However, Einstein could not arrive at physically meaningful results. Although his concrete physical conception of the geometrization of all fields proved impossible, this brilliant fundamental idea should not be thrown out altogether. Many elementary particle physicists continued to defend it. Heisenberg, for example, tried to work out a unified field theory of elementary particles. In quantum geometrodynamics the geometrization of physical processes becomes the foundation for the theoretical understanding of the behavior of elementary particles.

The aim of such a unified elementary particle theory is to reduce the qualitative variedness of elementary particles to a basic substance or to a few basic relations. Such a theory would be able to account for all types of reactions and properties with the aid of one or several basic equations and thus make possible the theoretical prediction of undiscovered reactions and objects. However, apart from its usefulness for physics, a unified elementary particle theory would also provide deeper insights into other fields of research: in chemical reactions, in organisms, in human beings — elementary particle reactions take place everywhere. Here, by the way, we

find an answer to the question frequently raised about the social usefulness of an elementary particle theory. No doubt, one could simply dismiss the question by pointing out that basic research reveals its significance for human society only after much time has passed. Igor Tamm noted that Heinrich Hertz, when asked about the practical purpose of the electromagnetic waves he had discovered, replied: "They will never have any practical significance." A few years later, wireless telegraphy was invented. Tamm does not share the scepticism of many scientists about the useful application of an elementary particle theory.[15] The first results are already before us. In medicine, pion therapy is being used in place of X-rays for the treatment of cancer. Muons may serve to measure the speed of chemical reactions.

Kashluhn gives the following reasons for the development of elementary particle physics in highly industrialized countries. It is not only the increase in knowledge about nature, but the usefulness of this knowledge. "Extrapolating from history, one can hope for or expect tangible useful results. At the moment, however, nothing exact can be said, as this field is still changing rapidly, and we are too far from the stage of possible application. Yet one cannot overlook, even today, its effects on other branches of physics and even on technology, for example, the use of certain mathematical methods for solid-state physics or the techniques of data processing and automation of measuring processes. In addition, it is generally admitted that high-energy physics is necessary today if one wants to achieve a high level of research in physics."[16] A unified elementary particle theory, even if it has only a relative character, i.e., does not embrace all properties and relations, would of course increase the prospects for useful applications. Our understanding of the structure of matter would also be deepened. Kashluhn writes further: "It is the task of physics to reduce natural phenomena to a few basic laws, whereby a scientific understanding of our material world becomes possible."[17] The physicist advocates the idea, confirmed by practice, of the material unity of the world, because it can become the heuristic starting point for further progress in physics. So there are various reasons for the fourth attempt to create a unified theory, this time of elementary particles. Such a theory would have both theoretical as well as practical value.

The philosophical analysis of more recent efforts to unify our picture of nature must take into account an important idea that Lenin expressed at the beginning of this century when analyzing the latest discoveries of physics at that time. He polemicized with the view that there exists an "unchangeable essence of things," a "basic substance." According to him, the "essence of things" is also relative. It is determined by the degree of our penetration into the laws of nature, into the behavior of objects, and denotes the borders of our present-day knowledge. Lenin says that dialectical materialism insists on the relative character of our knowledge. He considered the electron and the whole of nature as inexhaustible (see footnote on page 50).

There is no evidence that Lenin was thinking of a simple spatial divisibility of the electron. What is important is the idea of the infinite complexity of matter which we may be able to perceive, but which we can never know completely. Lenin's thesis on the inexhaustibility of material forms and relations has been confirmed, at least in breadth. When Lenin wrote his book, the only elementary particle known was the electron. Today we know more than one hundred. The inexhaustibility in depth, which is also contained in Lenin's comments, can be taken as a pointer to seek deeper-lying relations. Many physicists interpret Hofstadter's experiments, in which he scattered electrons on protons and found deviations from the behavior of a point charge, as proof that nucleons have a structure. Others have been looking for partons or other structural elements of strongly interacting particles. The evidence that elementary particles have structure is a further confirmation of the Leninist thesis on the inexhaustibility of material relations on deeper physical levels.

This brief survey of the attempts to create a unified theory of nature shows us some of the problems that are involved. So far, all these attempts have failed, but this does not mean they were useless. On the one hand there was an objective tendency to formulate theories of a universal character. Its foundation is the material unity of the world. On the other hand, no evidence has been found so far for the existence of an absolute basic substance or an ultimate basic relation. This is why dialectical materialism had to add two essential ideas to make materialist monism complete:

1. *The unity of the world is a unity of qualitatively different types of matter, material forms and relations. They are linked together, emerge from one another, but cannot be completely reduced to one basic substance.* Qualitatively different laws act in different realms, and these laws are system laws for the behavior of elements in systems. The statistical nature of these system laws does not allow their reduction to dynamic laws, but the investigation of the laws governing the elements of systems gives us a new insight into the basis for the operation of system laws. For example, elementary particle processes enter as elements of chemical reactions and of the behavior of organisms. Therefore, chemical reactions and biological behavior may be better understood through elementary particle theory, but cannot be completely reduced to the laws of elementary particle reactions. The latter would mean denying the importance of statistical laws and returning to classical determinism.

2. The second dialectical-materialist contribution to monism is the *recognition of the infinite complexity of matter. This emphasizes the relative nature of our knowledge about the structure of matter.* New experiments bring new insights into the behavior of material objects. This does not mean that we are able to obtain full knowledge of the infinite universe or are attempting to measure or describe the infinite, because this is impossible. What we need to recognize is the relative historical limits of our cognition. We can only survey one part of the universe, discover the laws governing it, and from there extrapolate to unknown areas. During the course of cognition, unjustified extrapolations are corrected. As long as the results of our experiments do not contradict the theories, speculative extrapolations need not worry us. This provides the possibility of searching for unified theories for all material processes, even if they later prove to be only unified theories for certain processes. The investigation of objective systems and their system laws, from which one can abstract from both the changes in the elements and the influence of other systems under given conditions, makes possible the discovery of objective truths.

The search for a unified elementary particle theory finds its justification in the experimentally confirmed transformability of particles into one another. This means they can constitute a self-contained system, as represented by Chew's "bootstrap" hypothesis, or by excitations of a field (as Heisenberg describes original matter). The view that the field is the ultimate basic substance of matter is one of those unprovable extrapolations which can do no damage at present, because they have no practical consequences. On the contrary, the search to confirm or refute them leads to the further development of the theory.

The efforts made till now to develop a unified picture of nature reveals the following tendencies in theoretical development. The intensive search for a unified theory of elementary particles continues. Basic particles, seen in the sense of basic relations, are taken to be the foundation of the theory. There are attempts to build the known particles out of others (Sakata, Markov, Gell-Mann, etc.):

quarks and partons. The weak interactions cause difficulties, because they are not adequately embraced by the theory. (See footnote on page 54.) Heisenberg tried to base his theory on basic relations derived from a field operator. Quantum geometrodynamics also tries to express the structural relations of elementary particles. In contrast to Heisenberg's approach, it considers space-time relations to be the simplest, and everything else is reducible to them. The structural relations in the domain of elementary particles is complicated. There are numerous particles with many ways of interacting. They interact with one another strongly, electromagnetically, and weakly.

The weakest of all is the ever-present gravitational interaction, whose significance for the elementary-particle theory is still controversial. An inner connection exists among the various interactions, and the particles transform into one another. The interactions occur in the presence of a connection between interaction and conservation laws. The weaker the interaction, the weaker the conservation law. This gives us the hope that the structural relations can be found despite the qualitative differences. Which of the relations are the most promising cannot yet be decided.

Modern unified theories thus take into account the qualitative differences of relationships, the growing complexity of the structures and the unity of structure and process. We can see how far we have gone away from the classical ideas of the behavior of objects and of a unified theory of nature, and how we must accept the infinite complexity of the unity of the material world, even in the search for unified theories.

Chapter Three
MATERIALIST DIALECTICS AND PHYSICS

After the foundations of mechanics were elaborated by Galileo, Newton, Huygens, and others, physics developed comprehensively and quickly. New theoretical fields arose: thermodynamics, electrodynamics, relativity theory, quantum physics. Currently, we are experiencing a tremendous upsurge in a number of areas such as high-energy physics, solid-state physics, astrophysics, and the thermodynamics of irreversible processes. The view expressed by well-known physicists at the end of the last century that physics is an almost completed science has been thoroughly refuted by reality, and no one would seriously make such a claim today.

The cause for this development lies principally in the connection between physics, technology, and material production, that is, the development of physics and the significance of this development are socially conditioned. Other causes are doubtlessly also to be found in the system and logic of physics itself and also in the demands made on it by other sciences. The decisive philosophical basis for analyzing this question is *materialist dialectics, the science of the most general relations of structure, motion, and development in nature, society, and thought.* The elaboration and successful application of materialist dialectics by Marx, Engels, and Lenin were truly great achievements. The inseparable unity of materialism and dialectics — the two necessary sides of a monistic, consistently scientific world outlook — essentially determines the new quality of Marxist-Leninist philosophy.

Materialist dialectics is the result of philosophical generalization of scientific knowledge and practical experience. If the laws and theories of the individual sciences are to reflect objective reality approximately and adequately,* they must replicate the objective dialectics of nature. The dialectics of the process of cognition is expressed in the nature of the questions raised, and in the approach and method of scientific activity. Engels commented one hundred years ago: "Dialectics divested of mysticism becomes an absolute necessity for natural science."[1]

Lenin, in his polemics with the "physical" idealism (see chapter 2, section 2) widespread among physicists and philosophers at the beginning of the century, comes to the conclusion: "It is mainly because the physicists did not know dialectics that the new physics strayed into idealism."[2] And further on he continues:

> In short, the "physical" idealism of today, exactly like the "physiological" idealism of yesterday, merely signifies that one school of natural scientists in one branch of natural science has slid into a reactionary philosophy, being unable to rise directly and at once from metaphysical materialism to dialectical materialism. This step is being made, and will be made, by modern physics; but it is advancing towards the only true method and the only true philosophy of natural science not directly, but by zigzags, not consciously, but instinctively, not clearly perceiving its "final goal," but drawing closer to it gropingly, unsteadily, and sometimes even with its back turned to it. Modern physics is in travail; it is giving birth to dialectical materialism. The process of childbirth is painful.[3]

The development of physics has fully confirmed both these statements. We see here once again that Marxist-Leninist philosophy, as a world view, epistemology, and methodology, provides a philosophical foundation for scientific activity. It is now important, however, that materialist dialectics be consciously made the basis of our activity in every field and that it be applied not only consciously, but with skill in the analysis of natural science, and moreover, from the very outset.

*The term *adequate*, in the philosophical sense used here, denotes a truth content corresponding to the appropriate degree of approximation, depth, and completeness required for the laws and theories to be used in a meaningful way.

1. Materialist Dialectics and the Development of Physics

In dealing with the relation between production and science from a historical viewpoint, Engels writes: "If, after the dark night of the Middle Ages was over, the sciences suddenly arose anew with undreamt-of force, developing at a miraculous rate, once again we owe this miracle to production."[4] Here, Engels is emphasizing the gigantic development of science that accompanied the emergence of the capitalist mode of production. The industrial revolution in the eighteenth and nineteenth centuries, as a unity of a technological and socioeconomic revolution, corresponded to the fundamental change in the social mode of activity as the necessary product of the change in the means of production. And this is what Engels meant when he said that a social need drives science forward much more quickly than ten universities together.

Since then, material production and science have become more and more interwoven. Without the knowledge acquired by science, modern production is unthinkable, science could never have developed the way it did without the close linkage between technology and production. Examples of this are the connection between the utilization of nuclear energy and the development of the theory of relativity, the connection between modern electronics and quantum physics, and the use of electrical energy and electrodynamics. All-important here is the interrelationship. On the one hand, problems for science arising out of the development of production, and the solutions to these problems, lead to the further development of science. On the other hand, science embraces knowledge, which is applied sooner or later, directly or indirectly, to production and thus helps develop the latter. *The relation between production and science therefore has a dialectical and contradictory character and thus acts as a driving force for both science and production.*

As a result of the close and direct link between science and production in our time, the socially conditioned character of science has become more marked and the social element in science is expressing itself more clearly, a development which impressively confirmed Engels' analysis:

> Only conscious organisation of social production, in which production and distribution are carried on in a planned way, can lift mankind above the rest of the animal world as regards the social aspect, in the same way that production in general has done this for mankind in the specifically biological aspect. Historical evolution makes such an organisation daily more indispensable, but

also with every day more possible. From it will date a new epoch of history, in which mankind itself, and with mankind all branches of its activity, and particularly natural science, will experience an advance that will put everything preceding it in the deepest shade.[5]

Without going into greater detail about the relation between science and society (see chapter 1), we can state that the decisive cause for the development of science is its dialectically contradictory relationship to material production, whose character is determined by the given social system. Another cause for the development of physics lies within physics itself, in its essence, namely, in the function it fulfills for other sciences.

We can explain this with the help of two examples.

1. Newtonian mechanics assumes the validity of the Galilean relativity principle, according to which the laws of mechanics have the same form in all inertial systems moving at constant velocity relative to one another. This means, in particular, that with a suitable choice of the relative velocity v of the inertial systems S and S' we find that from the Galilean transformation

$$x' = x - vt; \qquad t' = t,$$

we can obtain any velocity dx'/dt from any other velocity dx/dt.

To be free of logical contradictions the Galilean relativity principle must also hold for the propagation of effects. Velocities of propagation $v > c$ (c is the velocity of light in free space) must also be possible. When applying the Galilean transformation to the wave equation resulting from Maxwell's theory of electromagnetic fields in free space

$$\Delta E - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}E = 0\,,$$

we must allow for the possibility of a variable velocity of light. But in Maxwell's theory, the velocity of light is a constant and can be calculated from the electric and magnetic constants for free space. This means that Maxwell's equations are incompatible with the Galilean relativity principle. Voigt and Lorentz, on the other hand, proved that Maxwell's equations are Lorentz-invariant, that is, they retain the same form when the special Lorentz transformation

$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}; \quad y' = y; \quad z' = z; \quad t' = \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}}$$

is applied to transform the inertial system S into an arbitrary inertial system S' moving with a velocity v relative to S. This means that the velocity of light in free space is a maximum for the propagation of effects.

Here is a logical contradiction in the form of *p* and *not p*. According to the principle of the noncontradiction, $v > c$ and $v < c$, two logically contradictory statements, cannot be true at one and the same time. This contradiction was resolved by Michelson, who experimentally proved that $v \leqq c$. Einstein dealt with the problem theoretically in the special theory of relativity. According to the Einstein relativity principle, the laws of physics have the same form in all inertial frames moving at constant velocities relative to one another. The maximum speed for propagation of effects is independent of the frame of reference and is finite, that is, it is constant.

This means that Newtonian mechanics, which has proved itself valid in so many cases, is not false in all cases. It continues to be valid for speeds very much less than the speed of light. However, if the speeds are comparable to that of light, then its statements do not correspond to reality and must be replaced by relativistic mechanics. The connection between both theories is seen from the fact that the old theory (Newtonian mechanics) is contained in the new theory (relativistic mechanics) as a special case for $v \ll c$ and that for $v \ll c$ the Lorentz transformation goes over into the Galilean transformation. This can be summarized in the following diagram:

Newtonian mechanics	Maxwell's electrodynamics
$v_{\text{theor}} \gtreqless c$	$v_{\text{theor}} \leqq c$
Invariance with respect to the Galilean transformation	Invariance with respect to the Lorentz transformation

This logical contradiction is resolved in favor of $v \leqq c$, the decision being based upon practice (experiment) as a specific form of the criterion of truth. Relativistic mechanics is founded on this basis.

In this case, the starting point for the new theory was the logical contradiction between statements of two physical theories, in the final analysis between the possibility of a velocity $v > c$, in accordance with Newtonian mechanics, and the experimentally confirmed statement $v \leqq c$.

As reality was here, too, the criterion for the truth of scientific knowledge, it resulted in a theory which better reflected this reality, i.e., relativistic mechanics. The ratio v/c can be considered the measure of the new quality. In this way, relativistic mechanics is a dialectical negation of Newtonian mechanics, because it sublates it, overcomes it, and at the same time maintains it as a special case. In other words, it is a higher level of our cognition of reality. The new theory, however, also goes beyond the old, e.g., with the Einstein mass-energy relation $E = m \cdot c^2$, which has no equivalent in the old theory. At the same time, this advance in knowledge is also a step forward in unifying the theoretical foundations of physics.

2. The radiative power P of an accelerated moving electrical point charge Q is described in Maxwell's electrodynamics by the equation

$$P = \frac{\mu_0}{6\pi} Q^2 a^2$$

According to this equation, an electron orbiting the atomic nucleus should radiate electromagnetic energy and fall into the nucleus in about 10^{-11} seconds — in contradiction to all our experiences with regard to the stability and structure of atoms. Other facts, such as the existence of discrete spectra and the photoelectric effect, generalize and strengthen the contradiction between the statements of the theory and experimentally confirmed knowledge. As in the first example, here, too, practice is the criterion for the truth of a scientific statement. Experiments showed that all attempts to modify electrodynamics failed to produce a real correspondence with experience, so here one must conclude that the contradiction between theory and experiment results from the application of the laws of classical point-mass mechanics to the motion of electrons in the atom. The solution of this problem led to the development of quantum mechanics. This theory is in good agreement with experiment. It leads to far-reaching new knowledge and also to the unification of the theoretical foundations of physics.

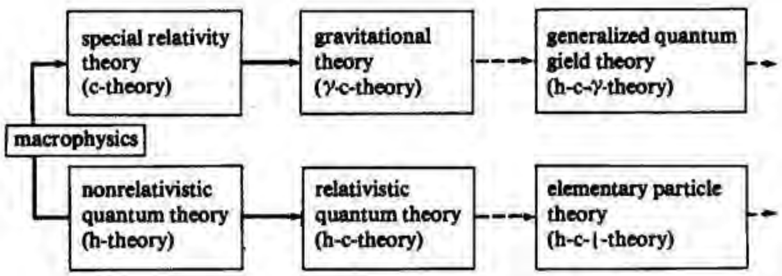
From a philosophical and epistemological viewpoint it is significant that Bohr, de Broglie, Schrödinger, Heisenberg, and other physicists who played an important part in working out the foundations of quantum theory, based themselves on the following principle: for high quantum numbers, the laws of quantum theory should go over into the corresponding laws of macrophysics. Quantum physics grasps reality more deeply and comprehensively than macrophysics; it is a higher level of our knowledge about reality. As a dialectical negation, the quantum theory goes beyond macrophysics and at the same time embraces it as a special case. Analogous considerations also apply to relativistic quantum mechanics, quantum electrodynamics, and other physical theories, as well as to developments in physics which are stimulated mainly through other sciences. An example of the latter is the development of the thermodynamics of irreversible processes far from equilibrium. Research in this area was stimulated in part by investigations into the physical-chemical foundations of life processes, for which the traditional equilibrium thermodynamics was too narrow.

In the following, we summarize and generalize the common features of these cases. *An important cause for the development of physics is the contradiction between various physical theories or between theory and experiment/experience. It is important to note that these contradictions do not arise out of reality, i.e., out of the physical objects themselves, but are an expression of the historical nature of our cognition, which ever more deeply and completely reflects objective reality. Thus, these contradictions are the cause and driving force of the advance in our knowledge.*

The contradictions are often formulated as questions, problems, or paradoxes which cannot be completely solved within the framework of existing theories and are the object of intense research. Therefore, it would be wrong to see them simply as defects. They are necessarily linked with the development of our cognition, which takes the course of recognition and solution of these contradictions. "Interesting in these inner contradictions is that on the one hand they limit the usefulness of the given theory only very little, but on the other hand, make the fundamental shortcoming of the theory clear."[6] It is important to note that new knowledge develops not in absolute separation from the old, but on the basis of it, that is, new knowledge sublates the old dialectically, as is expressed in the correspondence principle: *Every more general theory with claims to being true must contain the corresponding less general theory as a special case which embraces reality correctly in a certain area of validity.*

This general scientific principle is a good example of the negation of the negation in the development of physics and in our cognition of reality as a whole. It has great significance both for teaching (embodies the unity of the historical and the logical; shows why the extension of a corresponding theory is necessary and how it can be achieved; demonstrates the connection between various theories, etc.) and research (in formulating a new theory, one must verify that its assumptions lead to the substantiated conclusions contained in the old theory).

One possibility for classifying physical theories on the basis of their quality or place in the historical development of nature is by the natural constants typical for them. These make clear the new quality — as Engels had already noted — the differences of one theory from other theories as well as their interconnections, in line with the correspondence principle, that is, they express in a specific way the dialectical unity of continuity and discontinuity in the development of our cognition. In this spirit, the development of physics was represented by Strauss by the following diagram.[7]



These considerations and examples show that physics developed in line with the general law of the unfolding and overcoming of contradictions. Materialist dialectics in its totality provides us with the philosophical explanation. Its laws substantiate and explain our continually growing knowledge about objective reality. New contradictions develop at every higher level of our knowledge which, in turn, are the starting points for the further development of physics. Lenin points this out when he writes: "In the theory of knowledge, as in every other sphere of science, we must think dialectically, that is, we must not regard our knowledge as ready-made and unalterable, but must determine how *knowledge* emerges from *ignorance*, how incomplete, inexact knowledge becomes more complete and more exact."[8] This emphasizes the philosophical-epistemological significance of materialist dialectics for a truly scientific approach to teaching and research.

2. Materialist Dialectics and the Subject Matter of Physics

"Nature is the proof of dialectics, and it must be said for modern science that it has furnished this proof with very rich materials increasing daily, and thus has shown that, in the last resort, nature works dialectically and not metaphysically."[9] What Engels says here for nature in general applies to physics in particular. In the following, we will discuss important examples which show that the objective reality embraced by physical science has a dialectically contradictory character and consider how this is reflected in scientific cognition.

1. An object is determined by its difference from, and simultaneously its relationship to, other objects. This is expressed by the concept *interaction* (section 4, this chapter), which embraces identicalness and difference in a specific way. Because in physics it is not objects as such, but objects in their relationship to other objects, that is, in their law-governed connections, that are the subject of investigation, their dialectically contradictory character must be reflected in their scientific description. This is what Engels meant when he said that grasping things dialectically is nothing more than seeing them in their own interconnections. This is seen in physics through such concepts as force, mass, charge, and field, and above all in the fundamental laws and conservation principles.

Furthermore, in the individual branches of physics typical pairs of opposites appear. In mechanics, *attraction* and *repulsion*; in electricity, *positive* and *negative* electric charge; in high-energy physics, *particles* and *antiparticles*, etc. These are only a few examples of what Marx called the two-fold nature of objective reality. It has been principally in the field of high-energy physics that this recognition of the unity of self-causation and self-exclusion of real contradictory relations acquires great scientific methodological significance. Thus, it can be shown that for every elementary particle (except the photon, the neutral pi-meson, and a few other mesons) a corresponding antiparticle exists. Particles and antiparticles have many properties in common, such as mass, spin, isospin, and lifetime. This expresses the unity of opposites — the opposite poles in an interconnected system. They differ in properties characterized by chargelike quantum numbers (for fermions we have to include the parity); the magnitudes are equal, the signs are opposite. "In the philosophical sense, both particles of the pair are antiparticles to one another; to be an antiparticle is not the exclusive property of a particle, but expresses the mutually negative relationship of each particle of the pair."[10]

A mechanical approach to the unity of opposites must, however, be avoided. As Stiehler comments:

> It is correct that every phenomenon must be seen as a unity of opposites, but it is wrong to say that every characteristic of a phenomenon must be matched by an opposite characteristic within the very same phenomenon. This statement says nothing about the fact that by no means do all possible contradictions constitute a unity, and that the existing opposites differ according to their particular weights or dominance. If one does not take this into account, an eclectical "on the one hand, on the other hand" inevitably results, which does not take us one step further toward acquiring knowledge of reality and transforming it, but proves to be a big obstacle, because it replaces concrete analysis with jargon.[11]

The methodological significance of the basic principles of materialist dialectics is thus displayed. Materialist dialectics provides the means for understanding both the value and limits of the methods employed in the individual sciences and thus helps us to generalize philosophically the fundamental knowledge of the individual sciences. This is why training in dialectical thinking and the conscious application of dialectics are of such importance.

2. A further important form of phenomena in physics is the unity and struggle of opposites in static and dynamic equilibriums. In a solid body, for example, the internal forces among the elements operate in accordance with the law of action and reaction by pairs, mutually cancelling each other so that a balance of opposites exists. Thus, a static equilibrium follows as a necessary condition for the body. In the case of a dynamic equilibrium, which is of great importance in thermodynamics, chemical reactions, crystal physics, etc., there is continual motion in the form of an exchange of the elements of the system without the state of the system being changed in every case. In all fields of physics, states of equilibrium play an important role. Therefore, we will discuss some general questions about the subject.

When we consider a state of equilibrium, the aspects of rest and stability come to the fore. If we further consider any definite object, we assume that it is in equilibrium with respect to its differences with other objects for a longer or shorter time. This is how the structure and relative stability of objects embrace the unity and struggle of opposites in a way that is characteristic of the objects. The unity of these contradictory sides determines the quality and

stability of the objects. This is a specific expression of the philosophical cognition of the unity of matter and motion, the fact that in reality there are no absolutely closed systems and that the equality of opposites always lies within certain limits, that only dynamic equilibriums exist in objective reality. In physics, a dynamic equilibrium is an important and relatively independent form of dialectical contradiction. A static equilibrium turns out to be the external appearance of a dynamic equilibrium, every equilibrium carrying within itself the tendency for its own sublation. Here, too, we see that the unity of opposites is relative, but the struggle between them, absolute. Hence, a dynamic equilibrium includes motion, and the presence of this motion does not initially lead to the destruction of the equilibrium within the boundaries of which this motion occurs.

This approach to the problem of equilibrium is not only confirmed by the philosophical generalization of our physical knowledge, but has proved useful for cognition in the microworld. Here are some examples:

a. The existence and relative stability of atomic nuclei is attributed to the interaction between the nucleons and the virtual pions of the nuclear field. A continual exchange of pions takes place. The negative pion can only be emitted by a neutron and absorbed by a proton, the positive pion can only be emitted by a proton and absorbed by a neutron. During this exchange process, the protons and neutrons are transformed into one another.

b. The emission and absorption of photons — the quanta of the electromagnetic field, in a state of dynamic equilibrium, determine the quality and stability of electrically charged particles.

c. The chemical covalent bond is explained in terms of the exchange reactions involving the valence electrons of the atoms in the bond and is a consequence of the indistinguishability of the electrons.

3. Temporal changes in the state of physical systems are embraced by equations of motion. The contradictory character of motion, understood both as temporal change of place and change of state, is a further expression of the dialectical nature of the objectively existing physical world. A remark by Engels, based on a statement of Hegel, is of fundamental importance for an understanding of this problem: "Motion itself is a contradiction: even simple mechanical change of position can only come about through a body being at one and the same moment of time both in

one place and in another place, being in one and the same place and also not in it. And the continuous origination and simultaneous solution of this contradiction is precisely what motion is."[12]

If we accept the concept that motion, which in philosophy denotes any change, is the general mode of existence of matter, it then follows:

a. that general motion exists in concrete forms—in physics as mechanical motion (displacement), as change of state, as transformation of elementary particles, etc.;
b. that the philosophical concept of motion cannot be reduced to one of its concrete forms;
c. that the source of motion is the dialectical contradiction existing within all things, so that they need no external impulse — motion is brought about by self-movement.

Quantum physics made it particularly clear that motion is inseparably connected with physical objects, a fact which is expressed in its conceptual apparatus and mathematical representation. Thus the physics of the microworld has led to a deeper understanding of this connection, which must now be a fundamental part of every theory.

4. Motion in general includes development. The historicity of the laws of nature in the domain of the physical sciences is bound up with the historicity of all of nature. Research into this question, at the present state of knowledge, is the task of both philosophical and physical research. Investigations in this direction are called for because the philosophical questions connected with the theory of development are of growing importance, not only for an understanding of society, but also for other fields, such as biology and geology, as well as for physics. An interesting and important comment on this question was made by Engels: "It is true that nature was obviously in constant motion, but this motion appeared as an incessant repetition of the same processes. Kant made the first breach in this conception"* and thus shattered the idea that "nature had no history in time."[13] And elsewhere he says: "It is therefore from the history of nature and human society that the laws of dialectics are abstracted. For they are nothing but the most general laws of these two aspects of historical development, as well as of thought itself."[14]

To illustrate how questions of development are gaining importance in physics, too, we can consider a problem in cosmology.

*Kant's nebular theory, first published in 1775, that cosmic bodies originated from rotating nebular masses. — Authors

Cosmological models of evolution constructed on the basis of general relativity theory have been confirmed to a certain degree by the observation of the red-shift in the electromagnetic radiation emitted by galaxies. According to this model, the universe is expanding. If one now assumes that this law is eternal and operates continuously in the same manner, then, by calculating back twelve to fifteen billion years, we arrive at the so-called cosmic singularity and thereby encounter a contradiction with Einstein's equations. This is declared by idealists to be "proof of the Creation." Physicists, however, can provide an explanation that coincides with Marxist-Leninist philosophy and in particular with its conception of development. According to Hans-Jürgen Treder, a specialist on general relativity, "This contradiction leads us to the conclusion that either the state of matter in outer space was very different several billion years ago, so that the assumptions about the physical state of the cosmos become invalid, or that the simple identification of the mathematical quantities of relativity theory with measurable astrophysical ones, which form the basis of the world models, is not correct for an arbitrarily large period of time."[15] Thus, we would conclude that a cosmic singularity is a sign of the historicity of the natural laws, whereby qualitative changes in the interconnections arise from changes in the conditions. If the unity of cosmic physics and terrestrial physics is taken into account, then it is clear that the significance of this problem goes far beyond this example.

All these considerations emphasize the fundamental importance of materialist dialectics for physical theory and the theory of development, and for the physical world that is the subject matter of these theories, and they confirm the words of Frederick Engels that dialectics as a science and method is "an absolute necessity for natural science."

3. Dialectical Determinism

One fundamental task of science is to acquire knowledge of reality and, on the basis of this knowledge, to change it for the welfare of humanity. Knowing and changing have to be understood as a dialectical unity which is realized in the activities of human beings. As laws are the foundation of purposeful human activity, scientific cognition aims, above all, at discovering these laws, whereby "the concept of *law* is one of the stages of the cognition by man of *unity* and *connection* of the reciprocal dependence and totality of the world process."[16]

However, it is impossible to know the world as a whole and all at once, let alone through mere observation. We are confronted with reality always in the concrete form of individual objects, processes, and phenomena, and the task of scientific cognition is to find the general through the investigation, analysis, and study of the individual. This is a very difficult task, and the history of science shows us what huge and often tiresome efforts are needed.

For the investigation of individual things and phenomena it is of particular interest to know what their relation is to other things and phenomena; how they mutually condition and determine one another, what causes them, what their characteristics and properties are, and what laws apply to them. In Marxist-Leninist philosophy, this task is the subject matter of *dialectical determinism, the philosophical theory of universal interconnection, of the general conditionedness and the interaction of all phenomena, including the existence and action of the general and specific laws of nature, society, and thought.*

This definition of dialectical determinism shows the close connection between Marxist-Leninist philosophy and the individual branches of science. Questions such as that of the place of the human being in a deterministic world, the freedom of human action, and the possibility of scientific prediction, have always played an important role in the development of science and have always been the subject of disputes involving different world views.

The relation between determinism and science is many-sided. We should draw attention here to three particularly important aspects of this relationship:

1. The results of scientific investigations of definite processes and interconnections establish their deterministic nature and thus constitute an enrichment of our knowledge of the objective determination of things and phenomena.

2. Only on the basis of such comprehensive and scientifically confirmed material about the objective connection of things and phenomena can philosophical analysis and generalization be employed to develop a scientific view of determinism, which, in turn, provides a decisive epistemological and methodological basis for all research in any individual scientific field.

3. The social conditions must demand "the elaboration of a scientific world view of which the scientific view of determinism is a part."[17]

The above also applies to physics. We will now take a closer look at what this means for two problems in the development of physics and its relationship to philosophy.

a. Mechanical determinism and Newtonian mechanics

When Copernicus, Galileo, Kepler, Newton, and others elaborated mechanics, they created a physical theory which embraced a large number of differing phenomena. In the centuries which followed, this theory proved very successful. We recall here only the prediction and subsequent discovery of the existence of the hitherto unknown planet Neptune and the application of the laws of mechanics for the construction of machines, projectiles, bridges, etc. These achievements led to attempts to apply Newtonian mechanics, with its materialist and epistemologically optimistic, but specific fundamental, position, to other sciences. These attempts failed, and they showed that it is unjustified to raise Newtonian mechanics to the rank of a philosophical principle and apply it to all reality, as was done in mechanical determinism. Laplace expressed the program of mechanistic determinism in the following well-known statement:

> Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situations of the beings who compose it — an intelligence sufficiently vast to submit these data to analysis — it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes. The human mind offers, in the perfection which it has been able to give to astronomy, a feeble idea of this intelligence. Its discoveries in mechanics and geometry, added to that of universal gravity, have enabled it to comprehend in the same analytical expressions the past and future states of the system of the world.[18]

According to this view, reality operates with simple and direct necessity. All processes and phenomena, whether in nature or society, are linked through an absolute necessity, in accordance with the laws of Newtonian mechanics and can be accurately predicted — at least by Laplace's demon. The world is like a machine with an unchanging program which works by purely mechanical laws. Freedom does not exist, and the human being, at every moment of existence, is "nothing more than a passive instrument in the hands of necessity."[19]

This example represents a world view which was philosophically both progressive and revolutionary (namely, one that would explain all things and phenomena through their natural causes) and was very important for the development of physics and science. It can, however, turn into its opposite and become an obstacle for further progress.

It was Engels, above all, who discovered, criticized, and overcame the limitations and shortcomings of mechanical determinism. He discussed the problem in numerous writings and developed the basic features of a dialectical-materialist conception which has been confirmed in the course of its further development, particularly in the field of physics. Thus, the statistical character of the laws of quantum mechanics confirmed Engels' statement that it is not permissible to equate precise prediction with determination.

The possibility of prediction — the aim of every science and the expression of the knowability of the world — is a consequence of the law-governed structure of objective reality. Thus, one can say with absolute certainty that an object thrown into the air will accelerate as it returns to earth, that a spontaneously induced change of state which takes place in a closed system is irreversible and is linked to an increase in the entropy of the entire system, etc., even though it is not possible to predict with mathematical precision every single process in terms of a complete quantitative description of all effects.

No science can set itself the task of investigating every phenomenon, every effect accompanying a particular individual process. As Engels said, that "would be no longer science but pure trifling."[20] What is important is the knowledge of laws that make accurate prediction possible. The form of the prediction is determined by the type of connections and the character of the laws. Moreover, we must not equate the method and special forms of arriving at knowledge with the characteristics of the object under investigation. This distinction has played an important role in overcoming mechanistic views in physics.

Engels' arguments against mechanical determinism were based on his familiarity with progress in physics and depth of philosophical understanding, and to this day are a model for philosophical analysis of developments in natural science. In this connection, we should stress two points that are important for research or teaching in physical sciences.

1. *The relation between philosophy and a particular branch of science is not so simple that the results obtained in that science can be raised to the rank of philosophical principles through mere extrapolation.*

In chapter 1 we described why progress in science is of fundamental importance for the development of Marxist-Leninist philosophy, and why an understanding of Marxist-Leninist philosophy is important for every scientific activity, providing as it does a methodological, epistemological, and ethical foundation that has been theoretically substantiated and tested by practice. That is why physics cannot take over the tasks of philosophy, or vice versa. One must distinguish clearly between the subject matter and the specifics of both philosophy and physics. The use of philosophical terms does not necessarily mean that one is philosophizing. Great care must be taken when using terms such as *space*, *time*, *motion*, *law*, and *interaction*, which are used in both physics and philosophy, because they do not have identical meanings in the two fields.

2. *Practice must always be the starting point and touchstone of our knowledge.*

In scientific work we must uncover the laws and connections actually existing in reality through analysis and investigation and not impose them on reality from without. This is an inalienable materialist position of research into nature. Max Planck described this viewpoint with the words: "It is of paramount importance that the outside world is something independent of man, something absolute, and the quest for the laws which apply to this absolute appeared to me as the most sublime scientific pursuit in life."[21]

On the basis of physically unverified and philosophically impermissible extrapolation of some ideas and connections valid for mechanics, mechanical determinism put a constraint onto the whole of reality which in no way corresponded to it. As Engels comments, "The world clearly constitutes a single system, i.e., a coherent whole, but the knowledge of this system presupposes a knowledge of *all* nature and history, which man will *never* attain. Hence he who makes systems must fill in the countless gaps with *figments of his own imagination*, i.e., engage in *irrational* fancies, ideologies."[22] Criticizing such a view elsewhere, he says, "If I include a shoe-brush in the unity mammals, this does not help it to get mammary glands."[23]

However, we should emphasize here that the shortcomings of mechanical determinism do not lie in Newtonian mechanics, nor can it be claimed that Newtonian mechanics "corresponds" to mechanical determinism (see Röseberg, *Determinismus und Physik*).

The beginnings of a mechanical world view go much further back in time than Galileo, Kepler, Newton, etc. The Greek natural philosophers of antiquity attempted to explain the world in terms of only a few principles. The Atomists tried to explain all processes in terms of atoms and empty space alone, an approach that is clearly mechanistic. In the Middle Ages, there were attempts to explain the world in a purely mechanical way, i.e., through the mechanical motion of bodies in Euclidian space. At no time, however, was it possible to find a satisfactory picture of nature which permitted a unified scientific view embracing all processes of motion. Only when Newton succeeded in describing the basic laws of his mechanics in exact mathematical formulas, and applied them successfully to a variety of processes, was it believed that this goal had been achieved.

In his 1686 preface to *The Mathematical Principles of Natural Philosophy*, Isaac Newton states that "the whole burden of philosophy seems to consist in this—from the phenomena of motions to investigate the forces of nature, and then from these forces to demonstrate the other phenomena." After referring to his derivation of the "forces of gravity" from "the celestial phenomena," he adds: "I wish we could derive the rest of the phenomena of Nature by the same kind of reasoning from mechanical principles, for I am induced by many reasons to suspect that they may all depend upon certain forces . . . . These forces being unknown, philosophers have hitherto attempted the search of Nature in vain; but I hope the principles here laid down will afford some light either to this or some truer method of philosophy." [24]

The laws of Newtonian mechanics explain certain interconnections of objective reality, and they continue to be valid under certain circumstances. Mechanical determinism, with its unified mechanistic mode of thinking, makes relative knowledge impermissibly absolute with regard to both the range of validity and its accuracy, and gives a conceptually one-sided description of objectively existing interconnections.

In stating this today on the background of our present knowledge, we do not remain oblivious to the historical importance of that view.[25]

b. Determinism and quantum mechanics

A second area in which determinism is a much discussed subject, and has led to lively exchanges between philosophers and physicists, is quantum mechanics. Although the shortcomings of mechanical determinism had been revealed by Marx, Engels, and Lenin, this view was still held among philosophers and was fairly widespread among physicists. The ideal situation was considered to be one in which nature was described and explained in terms of isolated objects in absolute motion with the least possible disturbance of the actual physical processes by instruments, etc. This goal was considered to have been achieved if it was possible to express the law in the form of mathematically exact, nonstatistical laws according to the model of Newtonian mechanics. We can make this approach clear by citing the following comments by two outstanding physicists.

The first is Max Planck: "Therefore, in my view, as a postulate of physical science it is definitely in the interests of a healthy development to reckon with the strictly causal character of a law, and not at all only with the existence of a law, as is usually done up to now, and to consider the aim of research not to have been reached until every observation of statistical laws has merged into one or several dynamic laws."[26]

The second is Albert Einstein: "I am, in fact, firmly convinced that the essentially statistical character of contemporary quantum theory is solely to be ascribed to the fact that this theory operates with an incomplete description of physical systems. . . . . What does not satisfy me in that theory, from the standpoint of principle, is its attitude toward that which appears to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation or substantiation)."[27]

The fact that exact predictability was demanded after the pattern of Newtonian mechanics and was considered an expression of determinism shows that the attitudes of mechanical determinism still prevailed. However, the laws found in the quantum domain had a different structure and did not all agree with this demand. A wide discussion ensued, from which it subsequently became clear:

a. that mechanical determinism did not correspond to the new physical discoveries and was not a suitable philosophical foundation for understanding them;
b. that the form of connection in the laws of Newtonian mechanics is not valid everywhere, from which it can be

concluded that differing forms of connection exist in qualitatively different areas of objective reality;

c. that Marxist-Leninist philosophy, and dialectical determinism in particular, could provide an appropriate philosophical foundation for interpreting these scientific discoveries.

4. The Problem of Interaction

The focal point of dialectical determinism is the problem of interaction, that is, the Marxist-Leninist view of law and causality. This problem is playing an increasingly important role in physics. Among the problems encountered are: the determination of force as a quantity of interaction; the law of action and reaction; the interaction between object and instrument during measurement; and the various forms of interaction, namely, the gravitational, electromagnetic, weak, and strong interactions and their relation to conservation laws and symmetry properties. This is why physics shows such a strong interest in the problem of interaction. If one remembers that the world consists of one interconnected whole, that the various things and phenomena are reciprocally related to one another, that an important task of science is, precisely, to disclose these connections, then this interest is neither surprising nor is it limited to physicists.

The reason for the philosophical interest in the problem of interaction is the well-established knowledge that the world is an interconnected whole, that various things and phenomena do not exist in isolation, but influence each other, mutually condition and determine each other, that all phenomena are embedded into the universal connection, which, in turn, is differentiated and structured through laws and causal relations. It is therefore understandable that Marx, Engels, and Lenin aired detailed views on this question in their polemics against mechanical determinism. In its place they proposed a dialectical view of determinism on the basis of which we can describe the philosophical concept of interaction as follows: *The concept of interaction in Marxist-Leninist philosophy contains the universal and fundamental interconnection (that is, not reducible to other relations) of material objects which affect each other in various ways, condition, change, and determine each other, and are therefore not isolated but exist in reciprocal interdependence.*

We will now discuss this concept in greater detail.

1. The concept of interaction expresses the universal interconnection, the reciprocal interdependence and conditionedness of material phenomena without special limiting concretization. It is through this universal interaction that objective reality forms a self-changing, self-preserving, and self-determining system, that is, it is its own cause.

2. Interaction is universal, that is, there is no area of reality which is not in some way connected to other areas. These two features underline the philosophical significance of the Marxist-Leninist viewpoint on interaction: the world with its many phenomena and changes can be understood scientifically only in a dialectical-materialist way, only on the basis of itself, that no nonmaterial causes are needed to understand it, know it, explain it, and change it.

3. The epistemological and methodological importance of the foregoing concept of interaction is the following: What was at first considered undifferentiated, universal interaction is objectively differentiated into definite types and forms. For example, the form of interaction typical for society is different from that of the physical world. The latter can, in turn, be divided into the gravitational, electromagnetic, weak, and strong interactions.

4. The qualitatively differing forms of interaction existing in objective reality, which cannot be reduced to one another, condition the differentiation of matter and constitute its expression. The formation and existence of relatively stable material objects are conditioned by the existence of specific forms of interaction which link each element into one totality. This finds its expression, for example, in the structure of material objects, in their behavior in accordance with laws that are characteristic of specific types of interactions, and in the dialectical unity of conservation and change. Thus, the stability and structure of the atom are attributed to the strong interaction among the building blocks of the atomic nucleus and the electromagnetic interaction between the nucleus and the electrons, which, in their unity, determine the atom as a distinct material object in its difference and relation to other objects.

5. Concepts such as law, causality, and structure embrace certain specific forms of interaction. Engels points out in a number of places that the principle of causality can only be understood as a general interaction.

6. From the universal character of interaction and the circumstance that properties must be understood as specific types of interaction, it follows that properties, because of their inseparable association with interactions, are, at the same time, relative. The

relativity of properties also means that these can change, depending on the relationships within which they appear. It also means that there can be no absolutely fixed properties of material objects and processes independent of all interactions, just as there can be no absolutely isolated phenomena and processes.

This problem will be examined more closely later on. Here we wish only to point out that in the relationship between interaction and property, two aspects must be taken into account. When we say that a thing has a property, we mean, first, that this thing has the ability to act on another in a certain way, that is, that it presupposes the existence of another thing of some definite nature. Second, it is through the property that the specific character of a thing, and therefore the difference of one object from another object, is expressed, and in this way the property is inherent in the thing.

As an example, consider the property of the weight of bodies. Weight is the direct expression of the gravitational interaction. Weight cannot be understood in any other way except as a definite relation between bodies and their effect on one another. It is gravitation that determines the motion of the sun and the planets, that is, of the structure we call the solar system.

We will now deal with some questions of special importance.

a. Interaction and measurement

The act of measurement is an interaction between two physical systems, the measuring instrument and the measured object. This interaction causes certain information about the object to be registered by the instrument, which can then be read. The entire information obtained in this way, including the theoretical and experimental bases and the conditions under which it was acquired, is considered, in physics, to be the realm of experiment. Philosophically, it is very important to note that the experimental values expressed in statements, such as "The ammeter reads two amperes," cannot be separated into true and false statements — they are true in every case. It is here that the materialist foundation of physics finds its expression: to take nature as it is, without alien additions. Only in the process of generalization, of fitting the data into already existing theories, or formulating scientific hypotheses, models, and theories on the basis of this information, can false statements be made.[28]

Measurements are made on the basis of previously acquired

knowledge with the aim of gaining new knowledge about the investigated object. The instrument used must be appropriate for the object to be measured; they must be suitable to one another. This is because objects interact with other objects in a definite way as a result of their properties. The conditions of measurement are first fixed and then varied, and the changes are registered by the measuring instrument and recorded. It is, of course, possible that the conditions are not completely appropriate for the phenomenon under study or that the measurement is not suitable or is not sufficiently specific for the particular object that is to be measured. These inadequacies express the relativity and historical nature of our knowledge, but do not change the fact that the experimental values obtained in objective processes of interaction between the instrument and the object are true.

Concrete experience or experimental activity (called *practice*) is the starting point, aim, and criterion of truth of scientific statements. Experimental measurements are the specific form of practice in physics. The fact that the measurement is a specific interaction between object and instrument means that during the process of measurement, they have a reciprocal effect on each other, and thus both physical systems undergo change. It is precisely this problem that has been the subject of many discussions in physics. The epistemological and methodological questions linked to this are dealt with in chapter 4. The question here is: are the properties for the measured object established as a result of the measuring process valid for that object independently of the measurement, or are they valid only under that special set of circumstances?

In macrophysics we assume that the phenomena are independent of the conditions of observation, that is, the measurement, as an interaction between the object and the instrument, is one-sidedly reduced to the effect of the object on the instrument. It is assumed that the effect of the instrument on the object is negligibly small because it can always be held to within prescribed limits. This assumption was, of course, not just arbitrarily introduced by the physicists, but is based on extensive experience, as the following example will show. To measure the length of a macroscopic object a vernier caliper can be employed. The force from the caliper on the ends of the object changes the length of the object, so that the observed value is not the true value of the length. If a micrometer is used for the measurement, the distortion will be less. One can also use light. Then the effect of the light pressure on the ends of the object is so slight that the error in measurement can be ignored. And finally, some more refined instrument, unknown to us as yet, may have a still smaller effect on the object. We can consider another example. If the temperature of liquid iron in a furnace is measured with a suitable thermometer, the absorption of the thermal energy by the thermometer will not cause any noticeable change in the temperature of the iron. All measurements in macrophysics have an analogous character, which is why it was reasonable to assume that it is always possible to ignore the effects of the instrument on the object being measured. Fock[29] has pointed out a number of far-reaching consequences that are linked to this assumption. Let us consider some of the more important ones.

1. If the phenomena do not depend on the conditions of observation, then one can consider the properties of physical objects as absolute. This means that if some property is attributed to a macroscopic body, then the body has the same property before and after the measurement. It can then be said that this property is always inseparable from the body, no matter what the given conditions of measurement are.

2. If the properties of physical objects are absolute, then it is possible to divide physical processes into an arbitrary number of processes and refine the observation and measurement to an arbitrary accuracy without generally disturbing the physical process. Let us assume that with the help of various instruments the properties $E_1, E_2, \ldots, E_n$ were established for a body through measurement. Then this means that these properties can be measured singly without limit. The specific instrument is not then important. The properties can then be attributed to the body in the form of a conjunction of properties $E_1 \wedge E_2 \wedge \ldots \wedge E_n$, where $\wedge$ is a symbol for the logical *and*.

3. The specification of the state of a physical system means the specification of the instantaneous values of all independent quantities associated with the system. By *process of the system* we understand the way the state of the system changes with time.

We have already pointed out the scientific and historical roots of this view and the fact that the validity of these assumptions appeared to be well established. However, the development of quantum physics has brought out the shortcomings and limitations of these assumptions.

If we consider the connection between scientific labor and its results, it becomes clear that every measurement is a form of labor involving sense impressions derived from a particular object, which, like the results of scientific labor, must be seen as a unity of subjective and objective conditions. It is precisely through the active, purposeful action of human beings on the object of investigation, that is, the intentional changes induced in order to improve our knowledge of the object, that the passive and contemplative side of these assumptions and the rigid and absolute opposition of subject and object of cognition* in the epistemological process, are surmounted. This applies not only to the interactions accompanying the measurements, but, to the same degree, also to the goal of employing the instruments, which, themselves, are the result of scientific labor. With the development of Newtonian mechanics an ideal was proclaimed which became a feature of mechanical materialism: maximum objectivity in scientific cognition and a description of nature are achieved if the disturbing influence of the subject of cognition is completely eliminated. This aim proved illusory, and the objectivity strived for proved to be an "alien addition" to the extent that the dialectical interaction between subject and object was not taken into account. This philosophical truth, which was discovered by Marx, Engels, and Lenin, in time won acceptance also in physics, primarily through the development of quantum physics. Heated and even passionate debates took place around the problem of measurement and interaction.

The more the atomic domain was penetrated, the more it became obvious that the assumptions postulated for the physics of the macroworld could not be transferred to the microworld, that they even contradicted knowledge that had already been acquired. First of all, it has to be stressed that in the microworld it is impossible, in principle, to isolate the interaction between object and instrument during a measurement. The quantitative expression of this can be found in the fact that the terms containing Planck's constant h can no longer be neglected in comparison with terms not containing h. Equally important, however, is the qualitative aspect of this problem, which is of philosophical and epistemological importance: properties are not independent of the conditions of observation; physical objects are not "objects-in-themselves" without any relation to interaction, but are expressions of interactions and, like them, are also relative. We will illustrate this through an example provided by Heisenberg.

If we have the task of determining the position and momentum

*The *subject* of cognition (the scientist) is to be distinguished from the *object* of cognition (the physical object under investigation). The instruments, as an extension of the senses of the scientist, can be included within the concept of subject (see footnote on p. 27), rather than with the object.

of a microobject at a definite time we could proceed, by analogy to macrophysics, in the following way. First, we determine the position with the help of electromagnetic radiation. In this case, an interaction takes place between the photon and the microobject. The accuracy of the position determination depends on the wavelength of the light used. If we wish greater accuracy, we use light of a still smaller wavelength, i.e., with a higher frequency f. In accordance with the relation $E = hf$, a correspondingly larger amount of energy is used, which leads to a greater exchange of energy and momentum in the interaction between the photon and the microobject. To achieve greater accuracy, we need light of lower energy, that is, of longer wavelength, but this leads to greater uncertainty in the position. Macrophysics cannot solve this dilemma. The connection between position uncertainty and momentum uncertainty is characteristic for the atomic domain and is expressed by the Heisenberg uncertainty relation

$$\Delta x \cdot \Delta p_x \geqq \hbar/2 \, .$$

The assumptions of macrophysics, if applied to microphysics, lead to an obstacle to knowledge with far-reaching and much discussed consequences. Other ingenious mental experiments (see discussion by Bohr[30]) have all led to the same results.

Marxist-Leninist philosophy provides a fruitful basis for understanding the nature of the problem and a way out of the dilemma in a manner fully consistent with our physical knowledge. The foundation and starting point of our cognition is reality. If scientifically established results do not coincide with our ideas, then the latter must be brought into line with reality. Any other attitude is neither materialist nor scientific. If our scientific findings in the microworld do not fit into the confining concepts of macroscopic physics, that is, if they cannot be explained and understood with the assumptions of macroscopic physics, this means that we are dealing with a new quality in the microworld. Microscopic physics is not macroscopic physics with atomic dimensions. The specific characteristics and behavior of microobjects are revealed in their interactions. If properties appear only under certain conditions and interactions, then they apply only under these circumstances and not "in-themselves." However, this does not mean that an object exists only if we observe it. Microobjects also have properties which are quite independent of the conditions of observation. It must be the task of science to investigate an object under many different conditions, from many sides, and comprehensively, and to consider carefully the connections among property, interaction, and conditions. A much more comprehensive knowledge of reality is thereby possible than with the assumptions of macroscopic physics. Moreover, the activities of the subject of cognition do not create the properties registered by instruments; the results remain independent of the subject. A skillfully conceived interaction and change in the object does, however, make it possible to acquire knowledge more comprehensively, more completely, and in greater depth.

The specific features of the microworld express themselves in the wave-particle duality of atomic objects, in the character of the laws valid for this domain, in the conceptual apparatus, and, finally, in the technological application of our knowledge. Thus, the Heisenberg uncertainty relations and other laws not only do not become barriers to cognition, but reflect reality precisely because they express the specific nature of interactions in this domain much better than macroscopic physics and, at the same time, emphasize to a far greater degree the dialectical character of natural occurrences.

The measurement-interaction relationship can now be seen to lead to the following consequences:

1. A number of properties of microobjects are not independent of the conditions of measurement. They are the direct expression of the interaction between them, and likewise have a relative character. Knowledge of the object is obtained through its interactions. "This task does not exclude the introduction of quantities characterizing the object independently of the measuring instrument (charge, mass, particle spin), but at the same time it makes it possible to investigate that side of the behavior of an object (e.g., the particle or wave aspect), the appearance of which is conditioned by the measuring arrangement."[31]

2. This means that in general it is impossible to separate out the effect of the measuring instrument on the measured object in a measurement, the latter being an interaction between the measured object and the measuring instrument.

3. Scientific cognition includes the active, dialectical interrelation between object and subject. Knowledge that is not dependent on the subject can be gained only through the human being consciously producing changes in the object within the framework of the governing laws.

We conclude this discussion by emphasizing that in the macroworld the quantitative effect of the instrument on the object can be ignored, but that in both the macroworld and the microworld the qualitative side, linked as it is to philosophical and epistemological considerations, must be taken into account.

b. The classification of interactions

If the world is an interconnected whole in which various things interact, in which they condition and determine each other within the totality of interconnections, then questions arise about how various types of observed interactions can be distinguished from one another, how these interactions are interrelated, and whether a classification is at all possible. These are long-standing philosophical problems which are exceedingly important for the cognition of reality and for the work of every scientist.

The starting point of our observations is objective reality. Here we see that various things relate to each other in many different ways, and that the universal interaction takes place in rather distinctive forms. These objectively existing forms of interaction can be classified by various criteria.

Thus it is possible to reorganize the forms of motion, which were classified by Engels on a *historic-genetic basis*, to one based on interactions. According to this classification, we must divide the forms of motion into inorganic, organic, and social, and recognize that each of these domains has a complicated structure of its own. Even if this raises many new questions, philosophically it is important to undertake such a classification because it covers not only the various forms of interaction, but also their interconnection.

Another possibility is to classify interactions on a *system-theoretic* basis. Here it is important to recognize that things that exist in reality differ from one another and, because of their properties, interact with one another in specific ways. Expressed simply, we have the following picture. The structure and properties of physical objects, including their differences, as well as their stability and instability, are determined by the internal interactions of the objects. Their direct or indirect effects on other objects are the result of external interactions, and thus there is a close connection between internal and external interactions. Many interesting questions now arise, such as the relation between the part and the whole, the existence of various levels of structure, and so on. For example, the internal interaction between the positively charged nucleus and the negatively charged electron shell is responsible for

the specific character and stability of an atom, the atom thus constituting a whole, it being distinguishable from other things. At the same time it interacts with other atoms, affects them, and is affected by them (external interaction). Its behavior is determined by a unity of internal and external interactions. If the external interaction is comparable to the internal, and is strong enough, the atom will cease to exist as an atom.

Classification *according to strength* is the most important way of classifying interactions in physics. It has been seen that, in the fields of interest to physics, the many phenomena can be reduced to only a few types of interactions clearly distinguishable from one another both in their natures and their strengths. In other words: "Nature is very economical in the choice of its interactions and unbelievably extravagant in the most varying types of combinations of these interactions, and in their phenomenal forms."[32] The fundamental interactions in physics are:

The gravitational interaction. This refers to the reciprocal effect among physical bodies expressed through their property of having weight. As this is a universal property of all physical bodies, it is also a universal form of interaction.

The electromagnetic interaction. This refers to the reciprocal effect of physical bodies arising from the property of electric charge. This interaction underlies all electromagnetic phenomena in the physics of the macroworld and the microworld.

The weak and strong interactions. These are of fundamental importance in the field of elementary particles.

These four different types of interactions in physics are clearly distinguishable by their respective strengths. Classification of interactions based on strength is, first of all, a quantitative classification.

Let us consider how to determine the strength of an interaction. The electromagnetic interactions take place through the exchange of virtual photons between electric charges. The smallest known electric charge is the elementary charge of the electron e, and the strength of the interaction between two electrons resulting from an exchange of virtual photons is proportional to e^2. This factor therefore appears in the expression used as the measure of the strength of the electromagnetic interaction:

$$\frac{e^2}{4\pi\varepsilon_0\hbar c} \approx \frac{1}{137}.$$

This expression is known as the Sommerfeld fine structure constant.

For a comparison to be possible among other forms of interaction it is necessary to use a quantity which can be applied to the various interactions. For a comparison with gravitation such a reference quantity can be the force. Thus, for the interaction between two point charges Q_1 and Q_2 separated by the distance r, Coulomb's law gives the force

$$F = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{r^2},$$

while for the gravitational interaction between two masses m_1 and m_2, Newton's law of gravitation gives

$$F = \frac{\gamma'}{4\pi} \frac{m_1 m_2}{r^2}.$$

In both cases the force is the common quantity which makes a comparison between these qualitatively different forms of interaction possible. By selecting the corresponding *coupling constants*, we can extend this comparison to the strong and weak interactions.

In this way we obtain the following ratio of strengths for the four fundamental interactions:

gravitational : *weak* : *electromagnetic* : *strong*

$$= 10^{-39} : 10^{-14} : 10^{-3} : 10^{1}.$$

This comparison based on strength is by no means exhaustive, but its importance for physics is that it includes the dialectical unity of quantity and quality over a very wide range, as we can see in the following:

1. The direct connection between property and interaction expresses itself in the fact that different properties are associated with different forms of interactions. The property of physical bodies called gravitational mass is associated with the gravitational interaction. The property of electric charge is associated with the electromagnetic interaction. Let us consider these two forms of interaction. It is important to note that these properties are inseparably connected with physical bodies. Gravitational mass and electric

Table 1. Interaction, symmetry requirements and conservation laws in Newtonian mechanics.

Conditions for the force	Symmetry requirements for the action $S = \int_{t_1}^{t_2} L(\mathbf{r}_n, \dot{\mathbf{r}}_n, t)\,dt$	Conservation law	Conserved quantity
$\sum_n \mathbf{F}_n = 0$	$S(\mathbf{r}_n, \dot{\mathbf{r}}_n, t) =: S(\mathbf{r}_n + \delta\mathbf{r}_n, \dot{\mathbf{r}}_n, t)$ Invariance with respect to translation in space	$\dot{\mathbf{p}} = 0$	$\mathbf{p} = \sum_n m_n \dot{\mathbf{r}}_n = \text{const}$ Momentum
$\oint \sum_n \mathbf{F}_n\, d\mathbf{r}_n = 0$	$S(\mathbf{r}_n, \dot{\mathbf{r}}_n, t) =: S(\mathbf{r}_n, \dot{\mathbf{r}}_n, t + \delta t)$ Invariance with respect to displacement in time	$\dot{W} = 0$	$W_{kin} + W_{pot} = \text{const} = W$ Energy
$\sum_n \mathbf{r}_n \times \mathbf{F}_n = 0$	$S(\mathbf{r}_n, \dot{\mathbf{r}}_n, t) =: S(\mathbf{r}_n + \mathbf{r}_n \times \delta\boldsymbol{\varphi}, \dot{\mathbf{r}}_n + \dot{\mathbf{r}}_n \times \delta\boldsymbol{\varphi}, t)$ Invariance with respect to rotation in space	$\dot{\mathbf{L}} = 0$	$\mathbf{L} = \sum_n \mathbf{r}_n \times m_n \dot{\mathbf{r}}_n = \text{const}$ Angular momentum
$\dot{\mathbf{p}} = 0$	$S(\mathbf{r}_n, \dot{\mathbf{r}}_n, t) =: S(\mathbf{r}_n + \delta\mathbf{v}t, \dot{\mathbf{r}}_n + \delta\mathbf{v}, t)$ Invariance with respect to a Galilean transformation	$\dot{\mathbf{s}}_0 = 0$	$\mathbf{s}_0 = \frac{\sum m_n \mathbf{r}_n}{\sum m_n} - \frac{\mathbf{p}}{m} t = \text{const}$ Uniform rectilinear motion of the center of mass

charge are not external relations of objects which can be strengthened, weakened, or be separated from the objects. This means that the interaction is necessarily bound up with the objects and determines their essence and specific natures. It is also worth noting that the electromagnetic interaction occurs always and only in connection with the gravitational, but the converse is not true. However, for the weak and strong interactions, we can state the following. As distinct from the properties of gravitational mass and electric charge, which have direct and indirect effects on other objects, the weak and strong interactions involve properties which more strongly characterize the relations within the system. This is reflected in the physics literature by the terms *property of the body* and *property of the system*, and is expressed in the relationships among the forms of interaction.

2. Interactions distinguishable by their strength have a number of other characteristics with which they are associated. Among these are conservation laws, symmetry relations, range, duration, and cross section.

Conservation laws are of great importance for physics and therefore we will first show the connection among interaction, symmetry requirements, and conservation laws for Newtonian mechanics in tabular form (see Table 1).

If we extend these considerations to the four basic interactions, we have the following remarkable results:

a. The stronger the interaction, the greater the symmetry and the greater the validity of the conservation laws.
b. The interaction can be understood as the exchange of virtual particles between the interacting systems.
c. The stronger the interaction, the shorter its duration and the larger its cross section.

These characteristics also are summarized in Table 2.

Many philosophically and physically interesting questions which cannot be satisfactorily answered at present are linked to these interrelationships, for example, the interconnection among different interactions; the "nature" of the weak interaction, which gains strength at higher energies and approaches even the strong interaction; the existence of fundamental elementary particles from which the presently known particles are formed. The answers to these questions demand both intensive research as well as collaboration among physicists and philosophers.

Table 2. Characteristics of the Fundamental Interactions

Form of interaction	Comparison of strength	Range m	Duration s	Binding energy	Interaction cross-section m^2	Virtual-particle exchange	Conserved quantity
Gravitational interaction	10^{-39}	∞	?	Sun-earth -10^{46} MeV; nucleon-nucleon 10^{-31} MeV	?	Gravitons	W,p,Q,A,L
Weak interaction	10^{-14}	?	10^{-10}	None	10^{-72}	Bosons	W,p,Q,A,L
Electromagnetic interaction	10^{-3}	∞	10^{-21}	Hydrogen atom -13.6 eV	10^{-61}	Photons	W,p,Q,A,L, Y,I_3
Strong Interaction	10^{1}	10^{-15}	10^{-23}	Deuteron -2.24 MeV; shortlived baryon resonance +156 MeV	10^{-53}	Gluons	W,p,Q,A,L, Y,I_3,SU(3)

Source: Lenk and Gellert[33]

W — energy; p — momentum; Q — electric charge; A — baryon number; L — lepton number;
Y — hypercharge; I_3 — isospin component; I — isospin; SU(3) — full SU(3) symmetry

We will end this brief survey with some comments on the general philosophical implications of the problem of interaction.

On the basis of our present knowledge we can say that the Marxist-Leninist view of universal interconnection and the reciprocal conditioning and determination of phenomena in a specific way enrich our understanding of the interaction problem. *Object-property-interaction* relations are an expression of the dialectics of interconnection and an aspect of the general relation between matter and motion. A quantitative comparison of qualitatively different forms of interaction is possible because comparable effects can occur. We often make use of this in a practical way, for example, the effects of electrical force are weakened, compensated for, or strengthened by mechanical force. An illustration of this is the Millikan oil-drop experiment. The philosophical significance of this fact can be seen in an indirect way. If the different interactions were completely independent of one another, then objective reality could be divided into domains, each of which should be distinguishable by a specific form of interaction unrelated to the others. However, this would contradict the fact that the different interactions are connected in ordered levels of development and strength as discussed above. Expressed in positive terms, this means that the relative independence of qualitatively different types of interactions is sublated in the universal interconnection of things and phenomena. *The structured nature of matter and the material unity of the world are two sides which cannot be absolutely separated. They condition and determine each other and embrace the dialectically contradictory nature of objective reality only in their unity.*

5. Causality and Law

If one accepts the view that the search for laws is bound up with the scientific explanation of observed phenomena, that the disclosure of their causes and conditions is one of the fundamental tasks of science, then it is clear that philosophical problems of causality and law have played a big part in the long tradition of collaboration between philosophy and the individual branches of science, including physics. It is therefore not surprising that nearly all the leading physicists have commented on this question at some time or other. The rise of mechanical materialism and the development of quantum physics were accompanied by passionate debates on questions relating to the validity of the causality principle, the possibility of the exact prediction of physical events, the knowability of the world, the statistical character of quantum-physical laws, and so on. One should not conclude that these problems are interesting only from the historical viewpoint. At the present time, too, the various philosophical directions differ in their views of causality and law. The differences arise from differences in world view and in epistemological and methodological approaches and are a specific expression of the conflict between dialectical materialism and the various forms of idealism.

a. Newtonian mechanics and the classical-mechanical form of causality

The macromechanics elaborated by Galileo, Kepler, Huygens, Newton, and others was the first mathematically elegant and systematically constructed physical theory to be based on experimentally confirmed knowledge and fully tested in practice. In the seventeenth, eighteenth, and nineteenth centuries, Newtonian mechanics was the most advanced and successful science. The successes achieved did not fail to influence the opinions and the attitudes of natural scientists working in other scientific disciplines. Consider, for example, the historically important discovery of the planet Neptune. When Newton formulated the law of gravitation he succeeded in expressing mathematically the connection (interaction) among all bodies by means of the property of gravitational mass. Accordingly, when a stone is thrown into the air it is subject to the same laws as the motion of the moon around the earth. When it became clear through careful observation that the planet Uranus deviated from the calculations based on the law of gravitation, despite exact consideration of all disturbing factors, one did not conclude that this law was invalid or inexact, but that another as yet unknown planet must exist. This is how firmly people were convinced that the laws of Newtonian mechanics were correct. When, in 1846, Galle actually did discover Neptune at the position calculated by Leverrier, many scientists and philosophers saw this as a further argument for the general validity of the characteristic way of thinking associated with Newtonian mechanics. Later we will discuss the consequences of this. First, however, we will examine the relation between causality and law in Newtonian mechanics.

The structure of the laws of Newtonian mechanics is such that if we know the state of a physical body and the forces affecting it, we can make a more or less precise mathematical statement about the earlier or later states of the body. The Hamilton formalism gives the mathematical form for this view of physical events. If the position coordinates q_i and the momentum p_i at the time t_i are given, one can calculate the values q_k and $\bar{p}_k$ at any later time t_k if the forces acting on the physical system are known. For each physical event occurring under specific conditions (C) there exists only one possibility (M) which is necessarily realized (R) in accordance with a certain law (L). In symbolic form:

$$C : L \in M \xrightarrow{\text{necessary}} R.$$

This conception of Newtonian mechanics, as expressed in the structure of its laws, is tied to some other premises such as: physical phenomena are independent of the conditions of observation; the properties of physical bodies have an absolute character (nonrelativistic and unchanging). If the premises are true, then the laws of Newtonian mechanics afford an adequate description of the reality embraced by them.

The corresponding form of causality was expressed as follows: If the state of a physical system, i.e., the position coordinates and momenta, and the forces affecting it, is known with absolute precision at a given moment of time, the state of the system at any other time can be predicted with absolute accuracy. Characteristic of this classical-mechanical form of causality is the assumption of precise predictability.

If a comparison of law and causality is made under this conception it becomes obvious that they are identical. We should emphasize at this point that such forms of law-governed and causal connections do indeed exist in reality and they are adequately expressed by Newtonian mechanics. This does not exclude the existence of other forms of interconnection in reality not embraced by that theory.

The serious error which is made here is not contained in the physical theory, but in the limitations of mechanical materialism, and it arises when the results achieved in one science — in this case mechanics — are philosophically generalized in an unjustified extrapolation of a form of interconnection characteristic for one specific branch of physics to other branches of physics and to all of reality in general (see Röseberg, *Determinismus und Physik*).

Thus the whole world — nature and society — was seen as a gigantic system which exclusively obeyed the laws of mechanics. Before making a detailed critical analysis of this viewpoint, we can point to two important facts:

1. We have already mentioned that for a long time mechanics was the most advanced and successful of the sciences. The reason for this was that the technologies used for the rapidly developing capitalist relations of production (machinery and sources of motive power) operated almost exclusively on mechanical principles and that mechanical motion is the simplest and most easily understood form of motion of matter as well as the basis for more complicated, higher forms of motion. Commenting on the epistemological aspect, Engels writes: "The investigation of the nature of motion had as a matter of course to start from the lowest, simplest forms of this motion and to learn to grasp these before it could achieve anything in the way of explanation of the higher and more complicated forms. Hence, in the historical evolution of the natural sciences we see how first of all the theory of simplest change of place, the mechanics of heavenly bodies and terrestrial masses, was developed."[34]

2. In view of the historically conditioned level of knowledge at the time, this mechanical view of the world was progressive and exercised a stimulating influence on the development of science and society as a whole. Above all, it opposed the Aristotelian and scholastic world view — the mystical and speculative view of reality that was widespread during the Middle Ages. Moreover it developed on a materialist foundation. "This mechanical world view in which the whole of the natural occurrences is explained through mass points and forces, is based on a strong materialist causality viewpoint. Independently of the particular philosophical outlook of the individual scientist, the scientific system is atheistic and is incompatible with the acceptance of miracles. Divine interference not only is no longer necessary, but it would destroy the gigantic mechanism which the whole world represents."[35]

Nevertheless, direct transfer of the ideas and way of thinking of mechanics to all of reality does not correspond to the real relationship between philosophy and the individual branches of science, and it could not be done without having far-reaching philosophical and ideological consequences — impeding the development of science and a scientific understanding of reality in face of a continuing growth of knowledge.

Mechanical materialism has the following fundamental limitations:

1. The forms of connection typical for the realm of Newtonian mechanics are impermissibly extrapolated beyond the areas of experience of physics to all areas of reality and are raised to a philosophical principle. All things and phenomena are thus seen to stand only in a necessary connection and are determined by the motion of the smallest particles in accordance with the laws of mechanics. Chance is viewed subjectively as an expression of human ignorance. As all relations are of a purely necessary character and of equal rank and importance, law and causality are identical.

2. The failure to take into account the dialectical character of occurrences in nature, that is, a metaphysical view of reality, which Engels described as the "specific narrow-mindedness of the last century" is a further limitation of mechanical materialism and finds its expression in its conception of law and causality.

3. The failure to understand historical materialism, the improper, mechanical transfer of forms of interconnection from the sphere of nature to the sphere of human society is linked with unfortunate consequences and is an essential shortcoming of mechanical materialism. Lenin pointed out that such a transfer leads to idealism, and not materialism, in the social sciences.[36]

b. Law and causality in dialectical materialism

The impermissible oversimplifications of mechanical materialism and the shortcomings of idealist philosophy were revealed by Marx, Engels, and Lenin. The problem of causality and law was analyzed on the basis of dialectical and historical materialism. Of decisive importance for the solution of the problem was the examination of its direct relation to the basic principles of philosophy on a materialist framework. Hence, the law-governed behavior of objective reality is a fundamental requirement for its knowability and constitutes the basis for purposive activity of human beings. Causality provides a basis for the material unity of the world. It is part of the universal connection and expresses the direct reciprocal effects of things and phenomena on one another in the objective reality, which are realized in their interactions.

In his *Dialectics of Nature*, Engels comments:

> The first thing that strikes us in considering matter in motion is the interconnection of the individual motions of separate bodies, their *being determined* by one another. But not only do we find that a particular motion is followed by another, we find also that we can evoke a particular motion by setting up the conditions in which it takes place in nature, that we can even produce motions which do not occur at all in nature (industry), at least not in this way, and that we can give these motions a predetermined direction and extent. *In this way*, by the *activity of human beings*, the idea of *causality* becomes established, the idea that one motion is the *cause* of another.[37]

And elsewhere, when examining the relation between interaction and causality, he states:

> Further, we find upon closer investigation that . . . cause and effect are conceptions which only hold good in their application to individual cases; but as soon as we consider the individual cases in their general connection with the universe as a whole, they run into each other, and they become confounded when we contemplate that universal action and reaction in which causes and effects are eternally changing places, so that what is effect here and now will be cause there and then, and vice versa.[38]

Lenin, in his marginal comments on Hegel's *Science of Logic*, writes: "Cause and effect, ergo, are merely moments of universal reciprocal dependence, of (universal) connection, of the reciprocal concatenation of events, merely links in the chain of the development of matter."[39]

On this basis we can define the concept of causality in Marxist-Leninist philosophy as follows: *The category causality contains the direct influence of one phenomenon of the objective world on another phenomenon, the conditioning of one phenomenon (effect) on another (cause), and its unity.*

We will now briefly discuss this definition:

1. The concept of causality abstracts a fundamental form of the objectively real connection, the direct influence and determination of phenomena on and through each other. This means that causality is a part of the objectively real connection.

This characteristic of causality applies to both mechanical and dialectical materialism and differentiates them from all idealist viewpoints.

2. To understand all individual phenomena it is necessary to lift them out of their universal connection, and this is expressed in the terms *cause* and *effect*. As causality is one part of the objectively real connection, the abstraction necessary for scientific cognition must be superseded when one particular phenomenon is being considered in its universal connections. The concepts of cause and

effect then do not have meaning just for the artificially isolated process; with the help of them causality provides the means of comprehending the objectively real connection.

3. Causality refers to the single, concrete process. It does not differentiate between necessary and contingent, essential and inessential relations. This demands acceptance of differing relations and qualitatively different areas and supersedes the assumption of mechanical materialism that reality is the sum of necessary relations.

4. Causality is also characterized by the direction in time of cause (earlier) and effect (later).

5. The mediation of the objectively real connection by causality has a universal character, which means nothing other than that everything in the world is cause and effect, that there are no material changes which arise without causes and which do not produce effects.

If, besides the characteristic features of causality, one emphasizes their universality, i.e., the fact that all phenomena in nature and society have causes, then one speaks of the *principle of causality*.

This comprehension of causality shows us that it cannot be equated to law. While causality can be understood only as a moment (essential aspect) of interaction, and in this sense represents the simplest form of connection, the concept of law represents complex and complicated forms of connection, which, in turn, presupposes the causality principle.

In Marxist-Leninist philosophy a *law* is understood to be a general, necessary and essential connection among things, processes, and systems of objective reality, which are marked by relative constancy of conditions and reproducibility.

We will enlarge upon this briefly:

1. By *general*, or *universal*, we mean that the law for one class of connections embraces precisely those properties that are common to that class.

As Lenin noted, the universal can be a fragment contained in several individuals, an aspect of the individual, or its essence.[40]

The general, or universal, and the individual are dialectical opposites: they both condition and exclude each other.

The general, or universal, exists through and in the individual. Therefore, it is not an independent essence existing alongside the individual; it is the invariant in the transition from one element to another of the same class. "The form of universality in nature is *law*," notes Engels.[41]

2. *Necessity*, as the unequivocally determined connection between phenomena, has an objective character and stands in close connection with the universal. As Lenin said, it is "inseparable from the universal."[42] It is necessity that raises the universal connections to a law. If two events are in a necessary connection, then, in particular, it can mean that one event is clearly caused by the other event, that one property is due to only that process, thing, etc., that one event only follows another definite event, etc. Necessity, however, also includes the individual, singular event. Chance is complementary to necessity and is a phenomenal form of it; chance stands in a dialectical relationship to necessity, and, like it, has an objective character. This means that necessity and chance always appear together in reality, that their opposition is not absolute, but exists within the framework of certain conditions, that they can exchange places through a change in conditions, and during the course of development, necessity can turn into chance, and vice versa.

3. *Essence* is the unity of the universal and the necessary, it is the totality of the universal, relatively stable determinations, which of necessity belong to the process, things, etc. Lenin called *law* and *essence* . . . concepts of the same . . . degree, expressing the deepening of man's knowledge of phenomena, the world, etc."[43] Essence and phenomena condition each other: the essence appears in the phenomena, and the phenomena are the expression, the manifestation of the essence. The essence is relatively stable and invariable. At the same time, the phenomena are richer than the essence because they are the concrete form of expression of essence and as such contain not only the universal, necessary, and stable, but also the whole wealth of the individual, the chance, and the changeable. An important task of cognition is to penetrate the phenomena to the essence, to which Marx comments: "All science would be superfluous, if the appearance and the essence of things coincided with one another."[44] Included in this characterization is the feature of repeatability, which does not say that the phenomena repeat themselves, but that the essence repeats itself in the phenomena.

4. A law-governed connection always presupposes the existence of certain conditions. The dialectical-materialist view of law thus differs distinctly from the objective-idealist view. The action of laws is linked to the real process of the material world, in which the conditions for the operation of the laws also change. There is no room here for the divine impulse as a law.

5. Laws can be classified according to various features, for example:

a. general laws — specific laws;
b. laws of nature — laws of society;
c. laws of structure — laws of motion and development;
d. statistical laws — nonstatistical laws.

This division is based on different vantage points. Therefore, it should be noted, first, that a law is not completely described by one of the features indicated, but must be defined through all the features, and, second, that the classification (c) has no counterposition because laws of development also contain laws of structure and motion. With the development of higher qualities, accompanied by a significant change of structure, questions of the relation between continuity and discontinuity, etc., also arise.

The last class of laws (d) plays a major role in physics in connection with the extensive discussions on determinism. We will now take a closer look at this.

c. *The statistical nature of quantum mechanics and the relation between law and causality*

The development of electrodynamics by Faraday, Maxwell, and others dealt a severe blow to the mechanistic way of viewing things. Despite many efforts, it proved impossible to reduce the phenomena associated with the property of electric charge to mechanics. What was involved here was a qualitatively new fundamental form of interaction. The concepts of electric charge, electromagnetic field, etc., were united into basic physical laws in the form of Maxwell's equations in an adequate way. Of particular importance for us here is the fact that the electromagnetic field must be accepted as a physically real object in the same way as the particle in Newtonian mechanics, and that action at a distance was replaced by action by contact. This led to far-reaching consequences involving fundamental aspects of world view, as the further development of physics shows.

Let us consider only two problems relevant to the relation between causality and law.

1. The view that all qualitatively different phenomena can be reduced to quantitative relations, i.e., to the motion of particles in accordance with the laws of Newtonian mechanics, was insupportable. The specific features of the qualitative difference between electromagnetic phenomena and mechanical phenomena are correctly encompassed by Maxwell's equations. Newtonian mechanics and Maxwell's electrodynamics are physical theories which are not reducible to one another, and each corresponds to reality.

2. As a result of the confirmation of the objective existence of physical fields associated with action by contact, it was necessary to modify the views on causality. Since a limiting value exists for the propagation of signals (c — the speed of light in free space), not all events can be linked by a cause-effect relation. The theory of relativity, in particular, brought new insights on the problem by establishing that only events that were all timelike or all spacelike could be causally related, that is, events whose time and space coordinates satisfy the condition

$$(x - \dot{x})^2 \leqq c^2(t - \dot{t})^2$$

It should be noted that here we are speaking only about the possibility of causal relations. Whether or not a particular causal relationship exists must be established in another way.

Despite the new knowledge and despite the fact that Marx, Engels, and Lenin, through their development of dialectical and historical materialism, showed that it was necessary to abandon the impermissible oversimplifications of mechanical materialism, many natural scientists merely introduced a few minor corrections to the mechanistic approach. They continued to apply it to electromagnetic phenomena, and it dominated the scene for a long time.

Discussions on the validity of the causality principle, on the structure of physical laws, on predictability, on the relation between chance and necessity, etc., flamed up anew when it became obvious that the phenomena of the microworld could not be explained on the basis of the prevailing mechanistic views.

The uncertainty relation discovered by Heisenberg in 1927 played an important role in these discussions. According to this relation it is not possible to determine simultaneously the position and momentum of a physical object with arbitrary accuracy. But this is precisely the assumption for the conception of causality and law in macromechanics as described above in subsection *a*.

In a work published in 1927 Heisenberg wrote:

> But in the strong formulation of the causal law: if we know the present exactly, then we can calculate the future, it is not the final

> clause which is wrong, but the assumption. It is impossible for us in principle to know the present in all its determined pieces. Therefore, all perception is a selection from among a large number of possibilities and a restriction on future possibilities. As the statistical character of the quantum theory is so closely linked to the imprecision of all perception, one is tempted to suspect that another 'real' world is hidden behind the perceived, statistical world in which the causal law is valid. But such speculations appear to us . . . pointless and sterile. Physics must give only a formal description of the connection between perceptions. A much better description of the real facts is: because all experiments are subject to the laws of quantum mechanics, quantum mechanics definitively shows the invalidity of the causal law.[45]

As always, bourgeois ideology used these epistemological difficulties for its own purposes. Here is just one example. Referring to the uncertainty relations, Kühne writes: "Another conclusion from microphysics is the acausality of the laws of life and nature. Where we suspect there are laws, we have only rules. This applies not only to all aspects of life. The iron laws of nature, which are depicted in the pantheist forms of thinking as the mode of existence of God, are also subject to unaccountable changes. From here, scientific research reaches into the field of faith. The acausality of microphysics breaks through the barriers to biblical miracles which natural science has erected by its laws."[46] Thus, a physical law is supposed to establish the compatibility of natural science and religion to account for the existence of biblical miracles!

These and similar attempts to deny the possibility of scientific rationality (and made not only in connection with religion) are not just isolated cases, but are part of the variety of techniques employed by bourgeois ideology to use discoveries in the natural sciences to place obstacles in the path of a scientific approach to problems of social development.

Without going into the philosophical and epistemological problems connected with Heisenberg's views, we wish to stress:

a. that Heisenberg, like the majority of physicists at the time, understood "causal law" to be the classical-mechanical form of causality;
b. that the probability-theoretic features of quantum mechanics correspond to microphysical processes and phenomena and therefore cannot be explained in terms of insufficiency of knowledge, but are of objective character;

c. that Heisenberg, by concluding that the "causal law" is invalid because one particular form of it typical for a given causal connection does not apply to another domain, unjustifiably bases a sweeping philosophical conclusion on results in physics.

For a long time, other important physicists like Born, Bohr, and Pauli held this view, with small differences, while Planck, Einstein, von Laue, and others did not agree, and they adhered to the classical-mechanical conception of causality and law in its important points. Heated debates were held around whether the statistical character of the laws of quantum physics were a temporary expedient based on a lack of knowledge, which would be overcome in the course of time through laws like those of Newtonian mechanics, or whether the statistical laws had an objective character and were independent of our knowledge and consciousness, and whether the way they were expressed scientifically corresponded to the connections in the microworld.

The Soviet physicist V.A. Fock made an important contribution to the solution of this problem. In close collaboration with Marxist-Leninist philosophers he developed a consistent dialectical-materialist approach, which was in full accord with our physical knowledge of the microworld and which underscored what is specifically new in relation to Newtonian mechanics. According to the conception developed by Fock, the quantum-mechanical description of atomic processes is complete and refers to the motion of individual objects. The probability-theoretic character of the laws of quantum physics is conditioned by the specific nature of interactions in this domain. According to Fock, "Probability is to be regarded as an essential element of the description and not as an indication of the incompleteness of our knowledge; this follows already from the fact that, for given external conditions, the result of the interaction of the object with the measuring instrument is (in the general case) not predetermined, but has only some probability. A series of interactions leads to a statistics that corresponds to a definite probability distribution. This probability distribution reflects the potentiality that existed in the given conditions before the interaction had taken place."[47]

Fock points out that in macroscopic physics the probability concept is also used, but in a different sense. In this domain probabilities are introduced when one has insufficient knowledge about the initial conditions and one has to work around these unknown parameters. It is, however, always assumed that every particle belonging to the statistical ensemble moves in accordance with the laws of Newtonian mechanics. Therefore this probability expresses in the macroworld a certain incompleteness which, although unavoidable, is, in principle, eliminable. We note, however, that the theoretical basis of the statistical laws also continues to be discussed (Röseberg, *Determinismus und Physik*).

Emphasizing what is specifically new in the domain of quantum physics, Fock comments that "probabilities have a completely different character in quantum physics. There they are unavoidable by the essence of things, and their introduction does not reflect the incompleteness of the conditions, but the objective essential, potential possibilities under those given conditions."[48]

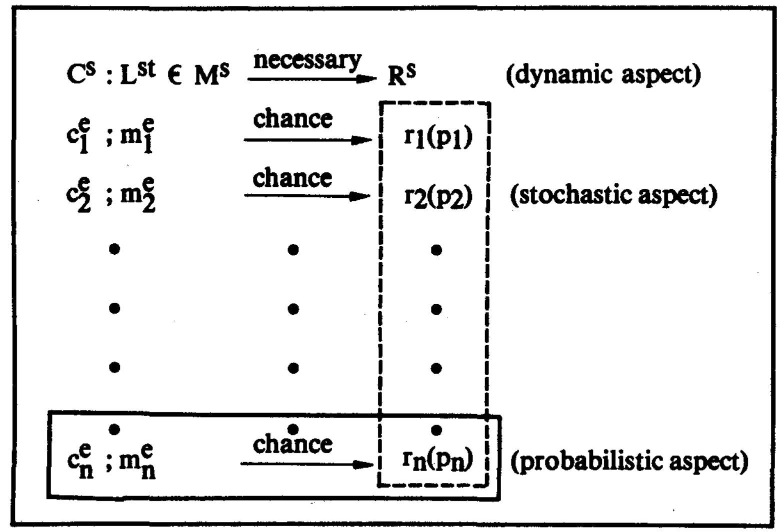
The statistical character of the laws of quantum physics is therefore objective and has its basis in the specific nature of the connection, that is, in the specific nature of the interaction of microphysical objects, whereby the objectively existing possibilities are an expression of the motion and are characterized in a quantitative way in terms of the probability. In this way we can give the following definition of a statistical law in which we take into account, from a philosophical view, the relations between the system laws and the behavior of the elements: *A statistical law is a general, necessary, that is, reproducible and essential, connection among things, processes, etc., in the objective reality which determines the character of the phenomenon*, whereby

a. the existing system possibility is necessarily realized (*dynamic aspect*);
b. the element possibilities are realized stochastically (*stochastic aspect*);
c. for an element there exists a probability for the realization of a definite possibility (*probabilistic aspect*).

This connection is summarized in the diagram on the opposite page (cf. discussion by Hörz[49]).

Thus the element possibilities are realized by chance, but with a definite probability. Mechanical determinism made the dynamic aspect of the statistical law absolute in a one-sided manner and identified it with causality. It did not take into account the system character of macroscopic physical objects and denied chance. The philosophical definition of the statistical law discloses the dialectics of system and element in a new light. It links the necessary realization of the system possibility with the chance realization of the element possibilities, the former following quantitatively determined statistical laws as a consequence of the stochastic character of the

latter. The laws of quantum mechanics are an example of such statistical laws. Here it should always be remembered that the individual aspects of a statistical law cannot be considered in isolation from, that is, without their connection to, other events. Stochastic distributions are not quite the same as statistical laws. The latter demand knowledge of those system possibilities which assert



L^{st} — statistical law

C^s — Necessary existence conditions (system conditions)

M^s — system possibility embraced by the statistical law

R^s — realization of M^s

c_n^e — conditions of the second order (element conditions)

m_n^e — element possibilities embraced by the statistical law

(p_n)— realization of m_n with the probability p_n

r_n — realization of m_n

themselves of necessity in the stochastic distribution. If an experimentally established half-life period is taken as an expression of a statistical law, then it is really only a potential statistical law, since it describes only a possible behavior, say, of a piece of uranium as it decays. It is a statistical law because the fractional number of atoms actually undergoing decay in equal time intervals is not exactly the same from time interval to time interval. The dynamic aspect finds fuller expression through the operation of the law of large numbers. Insofar as we are able, by a deeper penetration into the elementary behavior, to establish the precise character of the stochastic distributions or the transition probabilities, the potential statistical law becomes transformed into a quantitatively determined statistical law.

In regard to causality, this means that the form of causal connection typical for Newtonian mechanics is no longer valid for the domain of quantum physics. However, the classical-mechanical form of causal connection must not be equated or identified with the causality principle, which is, of course, valid for the entire domain of quantum physics, as it is for reality as a whole. The form of causality characteristic for the microworld can be defined as follows: ***Cause, as the real phenomenon which appears with the probability p_a, gives rise to and conditions another real phenomenon, effect, with the probability p_b.*** Causality expresses and focuses attention upon the essential aspect of motion. In the quantum-mechanical form of causality we take probability as an expression of possibility, and consequently as an expression of motion itself, and thus overcome the limitations of the classical-mechanical form of causality and, at the same time, include it as a special case. The dialectics of nature is more strongly emphasized through the *motion-possibility-probability* relations in the quantum-mechanical form of causality.

We will close this chapter with a comparison of law and causality. In a way, the concept of law goes further than the concept of causal relations. The category of law represents a wide range of different forms of general, necessary and essential connections, of which only a certain group has the character of causal dependences. On the other hand, the concept of causality, in a way, goes further than that of law, since not all moments of a given causal relation are included in the law, that is, causality embraces a wider variety of relations for a given phenomenon (see Korch, *Das Problem der Kausalität*). It thus follows that causality and law are not the same, are not equal, as we will further see in the brief remarks that follow.

1. Causality is the direct mediation of the connection. Knowledge of causality requires deeper penetration into the structure of matter, the discovery of more elementary mechanisms, which is why we consider it a fundamental form of connection. If we take into account the inexhaustibility of material objects and their relations, then the search for fundamental structures has no end. If the stress on direct and fundamental connections among objects and processes is not tied to the requirement of deeper penetration, these connections can be represented in an isolated way. This would lead to making causality absolute and to neglecting the objectively existing interaction among the inexhaustible objects and processes. The search for causality leads to law. It is not the direct and fundamental mediation of the connection that is examined, but the causes between the "beginning" and the "end," the general, necessary and essential relations occurring among coexisting objects and processes. It is not the stone that breaks the glass, it is not the falling body in the approximate vacuum that is the object of the complete description of the causal relations, but the reproducible, essential relations standing behind these chance events.

2. Causality is therefore the concrete mediation of the connection, undifferentiated with respect to necessity and chance, essentialness or inessentialness, while law embraces the essential, general, necessary relations behind these chance events.

3. Causality is asymmetrical, it is directed in time. It differentiates between past and future. The "initial" cause and the "final" effect, however, exist only as abstractions, since the direct mediation of the connection implies that the existence of the effects begins with the existence of the causes. Here, however, there is a direction in both time and content, which becomes obvious when the individual causal relation is linked with its history and its consequences. This asymmetry can be lost in the abstraction of a law. The direct and concrete asymmetry of certain processes need not be contained in the law, although the law may contain a time dependence.

If we stated at the outset that dialectical and historical materialism cannot be grasped through physics alone, this also applied to materialist dialectics. In our discussion we have applied the essential relations of this philosophical theory to physics, and we have concentrated on the connections of structure and motion in correspondence with the state of physical and philosophical research. Materialist dialectics, however, includes development, and this was discussed in section 1 of this chapter from the viewpoint of physics.

Physics is currently in the process of creating a mathematical-physical foundation for understanding objective processes of development in nature (time-dependent world models, processes of structure formation, etc.). Although, in the past, physics has contributed to the understanding of the problem of development, modern physics is practically only at the beginning of comprehending and describing the objective connections of development. That is why there is little philosophical literature on the subject. We can expect that in the future physics will provide valuable material for the philosophical elaboration of the dialectical-materialist theory of development.

Chapter Four
THE DIALECTICS OF THE PROCESS OF COGNITION IN PHYSICS

One of the advantages of Marxist-Leninist philosophy is its unity of world view, epistemology, and methodology. It is necessary to note this unity, particularly when separating the epistemological and methodological aspects in investigations of dialectical connections in the process of cognition. This is concretely expressed by the recognition of philosophical materialism, of dialectical determinism, and objective dialectics of nature as prerequisites for scientifically adequate research into epistemological and methodological problems. These basic philosophical principles themselves are the result of the philosophical process of generalization.

The most significant question of epistemology and methodology connected with world view deals with the source of our knowledge. We discussed in detail the materialist position on this question in chapters 1 and 2. The central question in the dialectics of the process of cognition is: How do human beings manage to acquire knowledge about the laws of objective reality and thus create the theoretical basis for their growing control over nature and society? The problem of epistemology and methodology thus always ranges from the production of knowledge and its application to, and confirmation in, practice. Thus. Lenin writes:

> The standpoint of life, of practice, should be first and fundamental in the theory of knowledge. And it inevitably leads to materialism, sweeping aside the endless fabrications of professorial scholasticism. Of course, we must not forget that the criterion of practice can never, in the nature of things, either confirm or refute any human idea *completely*. This criterion too is sufficiently "indefinite" not to allow human knowledge to become "absolute," but at the same time it is sufficiently definite to wage a ruthless fight on all varieties of idealism and agnosticism. If what our practice confirms is the sole, ultimate and objective truth, then from this must follow the recognition that the only path to this truth is the path of science, which holds the materialist point of view.[1]

The human being seeking knowledge about nature and society is a social being. Scientific research always takes place under concrete, historical conditions in society, which means it is always bound to a definite level of the productive forces, of the production relations, and of the superstructure with its specific ideology and world view. Just as scientists do not do research in isolation from society, the results of their work cannot be adequately understood philosophically when considered outside of the effects they have on the given society. These effects range from the lesser known publications in specialized journals, and their subsequent contribution to teaching and education in various fields, to practical application in material production or other areas of social activity.

In contrast to bourgeois philosophy of science, a class-indifferent epistemology and methodology does not exist in Marxist-Leninist philosophy. The aim of scientific cognition is the cognition of objective laws. The specific nature of the process of scientific research is not quite clearly determined by the dialectics of the productive forces and production relations. Therefore, a whole number of epistemological and methodological problems exist in which the class nature of all epistemology and methodology appears either in a very mediated fashion or not at all. About the firmly established axioms of geometry, Lenin comments: "If geometrical axioms affected human interests, attempts would certainly be made to refute them."[2] The same applies to problems of epistemology and methodology.

The dialectics of the epistemological process in the natural sciences cannot be represented as a formalized routine, with the use of which new scientific knowledge can automatically be acquired. However, it is possible to strengthen our consciousness of method

during the acquisition of scientific knowledge and, through subjective dialectics, to extend our understanding of the objective dialectics.

1. Theory — Method — Methodology

The results of the process of cognition in natural science and philosophy are expressed in concepts, hypotheses, and findings with varying degrees of certainty and universality. The aim of research in the natural sciences is to find the laws governing the behavior of objective reality and to reflect this through confirmed and proven scientific theories. We define a *scientific theory* as an *ideal structure to reflect a class of laws for a certain field of objects*. Marxist-Leninist philosophy considers the aim of philosophical research to be the deepening of the theoretical foundations of a scientific world view. Processes of cognition in the natural sciences and in philosophy have their own specific forms. What they have in common with all other forms of scientific cognition is that their starting point, aim, and criterion of truth is social practice.

As the history of science shows, there are scientific discoveries which, at first, are entirely without practical significance. One example is the theory of general relativity. Another is illustrated by Hertz's comment that Maxwell's electromagnetic theory was a fine physical theory which would never lead to any practical results. It was Hertz, however, who proved that the electromagnetic waves predicted by this theory actually do exist, and today they form the basis for various means of communication. It is often at first very difficult to assess whether new discoveries resulting from basic research in physics are actually of practical use. All fundamentally new scientific discoveries deepen our knowledge of the laws of nature. These new findings are incorporated into our current knowledge. This current knowledge, already confirmed to a certain degree through repeated practical application, is further refined, deepened, or corrected by new knowledge. Thus, scientific findings devoid of any relation to social practice do not exist, although these relations may very often be mediated through many links of a chain.

The fundamental discoveries of basic research in the natural sciences are very important for a scientific world view. In chapter 1 we described how the theoretical foundations of our world view are refined and deepened through the philosophical generalization of accomplishments in the individual branches of science, and thus become more effective both as a scientific guide for human action as well as in polemics with other world views.

Many philosophical problems are involved when practice is taken as the criterion for scientific truth. Let us first consider *how* scientific progress comes about, particularly in the physical sciences. We will start with the relationship between theory and method.

In the literature on this subject it often appears as though theory and method were metaphysically separated. While theory is considered a relatively stable result of the process of cognition, the method that led to this theory is seen as completely separate from it. On the other hand, one also encounters an equally impermissible identification of theory with method.

For the dialectics of the process of cognition, it is especially interesting to examine the relationship between the methodology of the natural sciences—in our case the physical sciences—and philosophy. On the basis of the conception described in chapter 1, we see that our knowledge about the dialectics of the process of cognition is deepened by the philosophical generalization of the methods used in the individual scientific fields, from which it also follows that the process of cognition for research in the physical sciences is advanced by the conscious use of materialist dialectics as a theory and method.

Philosophically, the *metaphysical* and *dialectical* methods differ. While the metaphysical method comprehends the world "as a complex of ready-made *things*," the dialectical method assumes that the world is "a complex of *processes*, in which the things apparently stable no less than their mind images in our heads, the concepts, go through an uninterrupted change of coming into being and passing away, in which, in spite of all seeming accidentality and of all temporary retrogression, a progressive development asserts itself in the end."[3]

This difference also affects the way one views the connection between theory and method. Engels makes clear that differing theoretical views about objective reality, acquired by philosophical generalization of the entire process of scientific cognition and practical human experience, form the basis for the differences in the two philosophical methods. An analogous situation applies, in general, to the connection between theory and method. Every theory sets up a methodological framework which determines the subsequent research in a given field. Every science has its specific methodological structure, which, like the theory, is subject to historical changes, but which sets it apart in a certain way from the other sciences. While physics, on the one hand, works with measurements

in the course of observations and experiments (experimental method) and, on the other, with the theoretical methods of mathematical physics, the methodological structure of philosophy is characterized mainly by philosophical generalization and the formulation of philosophical hypotheses.

As metaphysical thinking is always in danger of slipping into idealism, which can then lead to negative consequences for research in the natural sciences, it is important that the dialectical method be consciously applied to research in those fields, too. Philosophical methods, however, cannot be regarded as superior to other scientific methods. What was said in chapter 1 about the connection between theoretical cognition in philosophy and the natural sciences also applies to method, which means that no method of research in physics or in another science is metaphysical. The dialectical content of the methods used for the natural sciences must be disclosed through philosophical analysis. Only by going beyond the limits of applicability of a successful scientific method does one become guilty of being metaphysical. This statement, however, conceals a complicated problem. The limits of applicability of methods can be discovered only in the course of scientific research. They are by no means obvious in the explicit formulation of a method.

After the collapse of mechanical materialism, for example, the conviction arose that a new physics was needed to understand chemical and biological objects. Developments in physics since then indicate that this view must at least be critically examined. The physical basis for chemical and biological research has become very broad with the application of quantum mechanics and thermodynamics of irreversible processes far from equilibrium to problems in these fields. As before, there is still no reason to speak of reducing chemistry and biology to physics. After all, the physical-chemical methods are doubtlessly almost in a position to provide proof for the evolution of life. Research into biological objects and processes has not provided the slightest indication that a modification of the basic laws of physics is necessary. Therefore, the theoretical framework developed in physics for physical research on living things appears to be sufficient, at least for the near future, as we have not yet come upon the limits of applicability of our physical methods.

Research by dialectical materialists on methodological problems in the sciences is currently being stepped up. The effort here is to draw some conclusions, through philosophical generalization of methods used in individual branches of science, to further develop materialist dialectics, and to use the power of materialist dialectics heuristically for the further development of the scientific method.

In contrast to this line of research, a number of philosophers of science of neopositivist orientation are trying to draw up a catalog of scientific norms and to decide, on the basis of these norms, what is science and what is not. For such methodologists, everything that does not correspond to their logically normative "rational constructions" is "unscientific." While this has led to clarification of a number of important detailed problems of logic, it has erected impenetrable barriers to cooperation between philosophers of science and natural scientists.

Dialectical materialism, while overcoming the narrowness of the neopositivist concept of method, at the same time values a logical analysis of method. The advantage of dialectical-materialist investigations into the structure of method in scientific cognition lies in the fact that they take into account the dialectical unity of the historical and logical, the genetic and the structural, and the social and inner-theoretical influences on the development of science. Another strength of dialectics is that it does not try to reduce to one another the individual methods of physical cognition, the various paths to physical knowledge, or to see them in isolation from each other, but, on the contrary, it requires that the connections and transitions between each applied method be carefully examined. Engels pointed this out in his *Dialectics of Nature*: "Induction and deduction belong together as necessarily as synthesis and analysis. Instead of one-sidedly lauding one to the skies at the expense of the other, we should seek to apply each of them in its place, and that can only be done by bearing in mind that they belong together, that they supplement each other."[4]

2. Dialectical Relationship of Observation and Experiment to Theory — Dialectical Materialism vs. Empiricism and Rationalism

The question of how the laws of objective reality are reflected in scientific theories, how scientific cognition is at all possible, has often been discussed in the history of philosophy on the basis of physics. Here, two extreme viewpoints have been maintained to the present day, although modified in many ways and supplemented by a number of intermediate positions. These two extremes are philosophically characterized as *empiricism* and *rationalism*. The two main lines of philosophical confrontation, materialism and idealism, appear everywhere in these discussions. The separation between empiricism and rationalism, however, is not identical with that between materialism and idealism. There are both materialist and idealist positions in empiricism as well as in rationalism.

Empiricism assumes that knowledge can only be gained through experience (observation, experiment, measurement). The sensuous form of empiricism reduces experience to sensuous perception, but it also has a materialist version, as represented by Bacon, Locke, and the French materialists of the eighteenth century, who attempted to put it on a mechanistic foundation. They considered experience and sensuous perception to be the mechanical images of objective states of things, and the results of such perception were interpreted as arising from mechanistic processes of thought in the minds of the individual investigators.

Mechanistic-materialist empiricism had its historical counterpart in idealist empiricism. In the spirit of Berkeley and Hume, the positivists put forth various versions of a subjective-idealist concept of experience and made it the basis of corresponding epistemological positions. For example, Mach's philosophical discussions were based on a concept of experience which equated experience with complexes of sensations, out of which objective reality was to be constructed. He obviously accepted the subjective-idealist answer to the fundamental question of philosophy — for Mach, subjective perception was primary and objective reality was secondary, and was to be derived from the perceptions.

The problem of induction is important for all empiricist versions of epistemology. The task is to explain how one obtains the universal for a class of objects and structures from experience with the individual and particular. How, then, is it possible to arrive at knowledge of a law from an experience which is always historically limited, that is, how does one discover the general, necessary and essential connections of phenomena?

In contrast to empiricism, *rationalism says that thought (reason) alone is the source of human knowledge.* Human beings acquire knowledge about objective reality only by thinking. The senses and experience are not a solid foundation for rational knowledge because they can always deceive us. The metaphysical rationalist sees the rationality of human thought as an unchangeable human property and the most essential, an attitude also encountered in the present-day neopositivist philosophy of science, whereas the dialectical view says that rationality is a philosophical category subject to historical change (Hegel), about which there is no a priori knowledge.

In both rationalism and empiricism there is a materialist and an idealist line. The rationalism which goes back to the traditions of Democritus is materialist. Democritus saw the world as consisting of small, indivisible, qualityless objects (the atoms) imperceptible to the senses, but which could be the basis for a rational explanation of the wide variety of observable phenomena.

Descartes picked up Galileo's success with the mathematization of physical theories, and, in analogy to the atoms of Democritus, wished to provide a rational explanation of the objectively observable variety of phenomena with elements of mathematics. He dreamed of a universal mathematics which could contain the whole of human knowledge. This idea was taken up by Leibniz and others, and all objective reality was considered to be a mathematical structure.

The idealist line goes back to the traditions of Plato and Aristotle. For Plato, the "ideas" were a kingdom of their own, independent of the sensuous world. Although knowledge was stimulated by sense perception, this perception did not provide knowledge of the ideas which were ultimately the cause of all phenomena and objects. For Plato, knowledge came about through the memory of the soul which had lived in the kingdom of ideas before it entered the human body. Even modern idealist versions of rationalism contain — although in much modified form — such mystical moments of revelation without which knowledge remains inexplicable.

The problem of deduction plays an important role in all rationalist epistemological theories. There is always a need to explain how conclusions about the sensuously perceptible phenomena can be drawn from the fundamentally imperceptible elements of a rational explanation of objective reality. A consistent idealist rationalism is easier to maintain than a materialist rationalism, because the latter always must find a materialist explanation for the premises of its subsequent deductions. Since justification by experience is not accepted by this rationalism as its starting point, the premises can be justified only in the sense of a convention, or as knowledge gained through some form of revelation. In either case, an idealist foundation stands at the beginning of what is understood to be a materialist epistemology. This is a serious inconsistency.

Due to this inconsistency and the downplaying of experience, rationalism is unacceptable as the epistemological basis for a science like physics, based as it is on experimentation, measurement, and observation. Does this mean that the epistemological basis of physics should be sought in some form of empiricism?

There have been many attempts to prove that the success of physics since the time of Copernicus and Galileo is due to its empirical orientation. A feature of philosophical empiricism, however, is the strict metaphysical separation of supposedly "purely empirical experience" and supposedly "purely theoretical knowledge." Although the latter is supposed to emerge from pure experience, empirical experience in the form of measurements made during observations and experiment is said to be completely independent of all theory. Here, two problems arise. First, is there such a thing as purely empirical research? If so, one must show that it has dominated the development of physics up to the present. This is necessary if empiricism is to serve as the epistemological foundation for physics. Second, it should then be possible, in principle, to find an algorithm (presumably, as the result of a very complicated research process) that can provide a theory that corresponds to the experience of physical observation and experiment. If such an algorithm were found, theoretical research could then be done by a computer, while the physicists would concentrate on new observations, new experiments, and new measurements. The question is, therefore, whether the history of physics can provide any indications of such a possibility. For a defense of empiricism it would not even be necessary to provide the beginnings for such an algorithm — this already could be too difficult for us. It would be sufficient to prove that the importance of theoretical research decreases with the increase of knowledge.

The history of physics, however, shows us that empiricism cannot be an epistemological basis for physics. No purely empirical research has ever existed during the entire period over which physics developed. Experiment has always been directed to questions about nature arising in connection with important theoretical discussions about confirmed theories or promising theoretical approaches. Therefore, experiment has always answered questions which had been encountered within some appropriate theoretical framework. Apart from the many experiments performed to check certain statements of a physical theory or to provide empirical knowledge for a theory, many experiments in the history of physics have been performed for other reasons. For example, Oersted experimented with electric currents and magnetic needles to clarify the connection between electrical and magnetic phenomena as suggested by Schelling's natural philosophy. Experiments were carried out with the steam engine in the second half of the eighteenth century mainly to satisfy the needs of the rapidly developing industrial production in England and France. The first steam engine was built not only for practical and technical experience, but also out of theoretical considerations. It was not, however, an experiment to check and develop the then-current phlogiston theory of heat, but was a large-scale technological undertaking which led to the necessity of developing thermodynamics as a physical theory.

A careful analysis of the development of the productive forces, physical theories, and physical experiments in their interconnections can lead to many interesting details about the development of science.[5] It is possible that an enterprising and persevering historian may find examples of a purely empirical approach by physicists which contributed to the progress of physics. But our present knowledge is sufficient for us to state that a purely empirical approach, in the sense of philosophical empiricism, was never predominant in experimental research or in observation. There were, no doubt, many empirical observations which were not based on a theory of observed objects or a similar theoretical approach. This is still not an argument for empiricism, however, because in all aspects of such research there is also a close link between theory and practice. All observations employ a means of observation. The simplest are our sense organs, but more often we also use instruments. The result of an observation can only be accepted as an "empirical basis" for further scientific research if there is no doubt about what this result tells us about the objective behavior of the observed object. Thus, the dialectics of the investigating subject and the investigated object must also be taken into account in the experimental investigation of an objective occurrence. The aim of the experimental method is to gain knowledge about the object of cognition and its behavior, uninfluenced by the subject of cognition. To disprove an empirical interpretation of the observation, one must at least have a theory which explains the function of the instruments used for observation. This also applies to the experiment, because an experiment always ends with the observer's perception.

Contrary to the widespread one-sided emphasis on observation that is characteristic of empiricism, theoretical ideas about the observed objects and the criteria used to establish the truth of a theory often take on great importance. For example, the defenders of the Ptolemaic world view who opposed Galileo when his observations supported the Copernican theory, cannot just be dismissed as narrow-minded apologists for the Catholic Church. They defended a theory which had proved itself over centuries and which fitted very well into their view. For them, experiment and observation were not criteria for the truth of a theory. Galileo's arguments could not convince them, for they would have had to change their ideas about

the criteria of truth. And they probably saw no reason to do this, because Galileo's observations were valid only in light of his telescope theory and thus were only one argument against Ptolemy. Before Galileo, telescopes were not used to observe the heavenly bodies, whose exact position could be predicted by the mathematically complicated Ptolemaic system. Galileo's opponents were not prepared even to consider his arguments because they saw no reason to question their own theory of the heavens, which Galileo was now opposing on the basis of what they felt was his instrument theory.

In our polemics with empiricism, we need to find out if the history of physics provides any indication that the importance of theoretical research work is decreasing. This is fairly simple. We need only point out that a relatively independent theoretical physics has emerged since the middle of the nineteenth century, and its importance has certainly not decreased. But it has not developed in isolation from experimental research. The unity of physics continues to express itself in the unity of theory, experiment, and systematic observation. This unity has been achieved within the process of research, in connection with a far-reaching division of labor. Although experimental physicists cannot work without comprehensive theoretical knowledge, they can do experimental research without actually developing the theoretical side further. In the same way, theorists who wish to contribute to the development of physics cannot work without a knowledge of the results of experimental work, but they can do theoretical research without performing any experiments themselves. In the practice of physical research, many forms of cooperation between experimental and theoretical physicists have developed. This teamwork is gaining in importance. At the same time, however, the significance of the individual theoretical directions and experimental techniques and the responsibility of the individual investigator in the scientific division of labor are also increasing.

The underestimation of theory characteristic of philosophical empiricism is in gross contradiction to the actual development of physics and the other sciences. Engels made this strikingly clear more than one hundred years ago: "However great one's contempt for all theoretical thought, nevertheless one cannot bring two natural facts into relation with each other, or understand the connection existing between them, without theoretical thought. . . . Contempt of theory is evidently the most certain way to think naturalistically, and therefore incorrectly. But, according to an old and dialectical law, incorrect thinking, carried to its logical conclusion, inevitably arrives at the opposite of its point of departure. Hence, the empirical contempt for dialectics is punished by some of the most sober empiricists being led into the most barren of all superstitions, into modern spiritualism."[6] *Thus, empiricism cannot serve as the epistemological foundation of physics.*

Along with the stormy development of a relatively independent theoretical physics, rationalism is at present coming back into fashion. It often happens that empirically oriented scientists go over to rationalist positions after they have recognized that every empirical experience presupposes theoretical knowledge, that theory and practice cannot be separated. Because they lack knowledge of dialectics, they choose rationalism as the metaphysical alternative to empiricism, and postulate the almost absolute autonomy of theoretical science, and occasionally go to idealist extremes. Lakatos, for example, takes the development of scientific theories back to the world of Plato and claims: "The direction of science is determined primarily by creative imagination and not by the universe of facts which surround us."[7] There is no doubt that scientific progress without creative imagination is impossible. However, creative imagination alone cannot lead to knowledge about objective reality if it does not come into contact with it at some point. As the history of physics has often shown us, a complex of factors is at work here. We have had phases in the history of physical theories in which purely hypothetical, theoretical "speculations" have proved successful. Examples are Heisenberg's assumptions which led to his matrix mechanics or Einstein's ideas about the laws of nature, which led him to the theory of general relativity. However, it is impossible to conclude from this that the autonomy of theory alone makes scientific progress possible.

There is no doubt that the relative independence or autonomy of theoretical research is of significance for progress in physics. However a theory which has absolutely no contact with the results of observation and experiment is not a physical theory. Physics is a science which investigates the objective laws of nature. The truth of its theories can be established only if their consequences coincide with the results of observation and experiment.

Therefore rationalism, too, cannot serve as the epistemological foundations of physics. Physics, as a science that investigates the laws of objective reality, needs a sufficiently secure empirical basis. Empiricism, however, reduces the achievements of physics to this basis alone, and underestimates theoretical thought. Rationalism, on the other hand, overestimates theoretical thought and denies the need of an empirical basis for physics. What we must then do is investigate the multifaceted dialectical interconnections between measurements in systematic observation and planned experiment on the one hand, and the mathematized physical theories on the other. Here one finds many mediating links between the experimental and the mathematical-theoretical methods, such as hypotheses, models, and thought experiments.

A dialectical-materialist investigation of the methodological structure of physics leads one away from the metaphysical alternative—empiricism or rationalism. Such an investigation will lead us to the dialectical relationships among observation, experiment, and theory, and to the fundamental role of processes of measurement in the mathematization of physics.

Empiricism and rationalism are attempts at philosophical reductionism. Empiricism tries to reduce all knowledge to an empirical basis; rationalism tries to reduce all knowledge to reason. But even if empiricism and rationalism fail, this does not mean that all legitimate scientific reductions must be condemned. One must carefully differentiate between philosophical reductionism and well-founded attempts to gain scientific knowledge by means of reduction.

The attempts to reduce all phenomena of physics to a single physical research program, namely, to reduce physics to mechanics, brought a number of important results ("mechanical" theory of heat). In thermodynamics and electrodynamics these attempts ran into physical boundaries that Newton could not foresee. The attempts to reduce the laws of the whole to the laws of its parts, that is, system laws to element laws, led to a number of important intermediate results, for example, the theoretical basis for statistical mechanics (even though it was not possible to reduce statistical mechanics to the microphysics from which it arises). We have already noted that biological research has been enormously stimulated by the application of physical and chemical methods. The limits of all these attempts to gain new knowledge through reduction become recognized during the attempts themselves. The recognition of these limits provides us with arguments against philosophical reductionism, but the abandonment of such reductions on the grounds of their scientific incompleteness, would severely limit the arsenal of scientific methods available to us.

Empiricism and rationalism metaphysically separate the subject of cognition from the object of cognition in the process of cognition; rationalism refers the entire process of cognition back to the subject. The dialectical-materialist solution to the problem lies in the dialectical integration of subject and object on the basis of a consistent materialism. Thus, empiricism and rationalism, as we have shown, are equally unsuitable to serve as an epistemological foundation for physics. They are capable of explaining neither the possibility of scientific research nor the historically established progress made in the sciences. The solution lies in a dialectical-materialist synthesis of the rational elements of empiricism and of rationalism.

The aim and criterion of truth of scientific knowledge is practice. This is the thesis with which dialectical materialism opposes practicism, pragmatism, and all attempts, despite scientific progress, to leave room for agnosticism. Thus Jordan claims that physical research does not aim to "disclose the 'true' essence of things lying 'behind' the world of phenomena, but rather to develop systems of thought for control of the world of phenomena."[8] Dialectical materialism, however, shows that physical research aims at cognition of the laws of the essence of things, and that the process that leads to such knowledge, like every other process of cognition, is deeply dialectical. This is clearly expressed in Lenin's conspectus on Hegel's *Science of Logic*:

> Knowledge is the reflection of nature by man. But this is not a simple, not an immediate, not a complete reflection, but the process of a series of abstractions, the formation and development of concepts, laws, etc., and these concepts, laws, etc. (thought, science = "the logical Idea") *embrace* conditionally, approximately the universal law-governed character of eternally moving and developing nature. Here there are *actually*, objectively, **three** members: 1) nature; 2) human cognition = the human **brain** (as the highest product of this same nature), and 3) the form of reflection of nature in human cognition, and this form consists precisely of concepts, laws, categories, etc. Man cannot comprehend = reflect = mirror nature *as a whole*, in its completeness, its "immediate totality," he can only *eternally* come closer to this, creating abstractions, concepts, laws, a scientific picture of the world, etc., etc.[9]

On the road from the concrete objects of our immediate experience in experiment and observation to the abstractions of scientific theories, our thinking seemingly departs from reality. However, the analysis of the process of cognition shows that "thought proceeding from the concrete to the abstract — provided it is *correct* . . . — does not get away *from* the truth but comes closer to it. The abstraction of *matter*, of a *law* of nature, the abstraction of *value*, etc., in short *all* scientific (correct, serious, not absurd) abstractions reflect nature more deeply, truly and *completely*."[10]

How this "reflection of nature by man" comes about in physics we will now investigate by analyzing the connections among the individual methods we have discussed. It is necessary to elaborate the specific features of these methods without losing sight of the connections. It should become clear that in physics there are a wide range of methods whose boundaries are formed by the experimental method on one side and by the mathematical-theoretical method on the other. The choice of research method does not depend on a subjective arbitrary decision by the physicist, but is determined by the object under investigation, the level of knowledge, and the aim of the research. These factors, however, do not clearly indicate which is the best method for the research to be successful. The methods can involve systematic observation, experimental interference in the objective occurrence, and the search for possible relations among ideal objects. In order to arrive at scientific theories about objective reality, the connection between theory and the objective reality must be established. This is achieved by using the possible relations among ideal objects for representing the real relations among real objects, and the results are tested through experiment and observation.[11]

3. The Role of Observation, Experiment, and Measurement in the Experimental Method of Physics

Human beings have been observing nature for thousands of years. Again and again, they have generalized the experiences gained in the process of production in order to improve the instruments and methods of production. The Greek philosophers and mathematicians (Archimedes, Aristotle, Pythagoras, Ptolemy) variously referred to observation and experiment for the substantiation of their philosophical views. Only with the emergence of the bourgeoisie during the early bourgeois revolutionary period did there arise a natural science based on systematic observation and purposive experimentation which was able to provide a store of readily applied knowledge. It was Galileo who founded the experimental method in physics. He believed that through experiment physical research is capable of establishing a suspected law of nature. Galileo wrote:

> We have decided to consider the phenomena of bodies falling with an acceleration such as actually occurs in nature and to make

> this definition of accelerated motion exhibit the essential features of observed accelerated motions. . . . And this, at last, after repeated efforts we trust we have succeeded in doing. In this belief we are confirmed mainly by the consideration that experimental results are seen to agree with and exactly correspond with those properties which have been, one after another, demonstrated by us.[12]

Physics was the first natural science that, in accordance with the economic, technological, and philosophical needs of what was then the historically progressive bourgeoisie, elaborated a method which makes new and deeper insights into the laws of nature continually possible. Observation and experiment, coupled with the application of mathematics, have played a decisive role from the start. A precondition for, and constituent element of, the development of mathematized physical theories was the measurement of physical quantities in observation and experiment. Only on the basis of measured quantities can the values of theoretical constructions be projected and determined.

A methodology which emerged under certain historical conditions is also developed further and applied under concrete historical conditions. This is reflected in the presence of influences from the concurrent relations of production, level of productive forces, and superstructure (especially world view and ideology), although these influences enter in a highly mediated (indirect) way. The methods of physics, are, after all, directed at the discovery of objective laws of nature and the criteria for the truth of physical theories are in agreement with the results of observation and experiment. Therefore these methods, which are tools for the acquisition of knowledge, are relatively independent of the social conditions and continue to develop in relative independence.

Physical observations are purposive perceptions or measurements of definite physical properties in observed objects. Physical experiments are observations of definite properties of real objects and processes under partly controlled conditions which are consciously varied by the investigator.

The physical properties of real objects and processes studied by observations and experiment can be separated from their carriers only mentally. The fact that they appear only in interaction with other objects and processes does not always mean that they are formed in this interaction. Every material object and every material process has a number of objective properties which make it possible to remove this object or process from the universal interaction and thus create the objective basis for identifying this object or process, or at least a representative of a certain class of objects or processes, as objects or processes as such. As we generalize the results of the various processes of cognition, we conclude that the properties of all objects and processes, interacting with one another in a variety of ways, are inexhaustible and that we must concentrate on the essential properties.

Experiments and observation are distinguished by the fact that both the objects and processes to be observed and their properties are already embraced by the framework of existing theoretical knowledge. That is why, in our polemic against empiricism, we stressed the dependence of observation and experiment on theory. Neither the outcome of the experiments nor the results of the observations depend on the theory. *What* we observe, *how* and *with what* we experiment, depend on the theory. Meaningful observations must answer meaningful questions within the framework of definite theoretical views. Thus, we know through our everyday experience and on the basis of classical mechanics, it is meaningful to measure the position and velocity of heavenly bodies simultaneously. Quantum mechanics forbids us from extrapolating this experience to the realm of microphysics. Therefore, we would not even try to perform such an experiment on microobjects, because the laws known for this domain make it pointless.

The dependence of observation on theory is further expressed by the fact that it is impossible to formulate a completely theory-free observational language. If physicists speak of "velocity" they usually mean the concept used in classical mechanics. If, however, they want to make clear that one must take the relativistic view into account, they will speak of "relativistic velocity." But if one speaks of "velocity" in quantum physics, then every physicist knows that this concept is being used because of certain correspondence relations which connect microphysics and macrophysics. Moreover, the concept of velocity is defined in microphysics very differently from that in classical mechanics. The empiricism of logical neopositivism has failed to explain the fact that the linguistic expression of results of observation is formulated linguistically in a context that is inseparable from theoretical ideas.

Experiment has the advantage over observation of being able to create and vary the conditions under which the experimentally investigated objects and processes are to be observed. The only choice that we have in observation is to decide what we want to observe, but experiment gives us the opportunity to choose freely, in part, the conditions of experiment. From the evaluation of the experiment, conclusions can then be drawn about the corresponding behavior of objects and processes under conditions that are not influenced or controlled by the investigator. This is why the dialectics of subject and object in the process of cognition must be taken into account. From the behavior of the object of cognition, observed by the subject of cognition under controlled conditions, conclusions can be drawn about the behavior of the object independently of the subject of cognition. Thus the subject and object cannot be metaphysically separated nor is there reason to adopt subjectivism or demand objectivism from this fact.

In order to avoid such positions in practice, the total complex of experimental conditions must be analyzed. This means, above all, that one must be clear about the way the experimental situation breaks the entire complex of objective connections, and what influence the neglected conditions can have on the objective occurrences of the experiment. To determine this it may be necessary to carry out special tests in experimental arrangements under various conditions of isolation. The essence of the experiment is the objective analysis of the actual occurrences. In all theoretical generalizations of experimentally acquired knowledge, we must never forget that complete knowledge of all the experimental conditions is not possible, as we have seen from the dialectics of the process of cognition. Such knowledge is not even necessary. It is sufficient to know the essential conditions and take them into account. Otherwise relativism in experimental cognition would be unavoidable. However, it can happen that conditions which were originally considered inessential prove to be essential with the advance in knowledge. This can result from a refinement of the measuring technique or the discovery of previously unknown law-governed connections. Here we again encounter the dialectical relations between experiment and theory, which once more justifies the cognitive optimism of dialectical materialism.

All known laws can be used to establish the experimental conditions and the kind of measuring equipment to be employed. Laws can serve also as the basis for extensive conclusions about the unobserved from the observed. Thus, all additions to our knowledge of laws extend the relevance of the experimental act and thereby create better conditions for the cognition of hitherto unknown

laws. The synthesis of objective reality based on the analysis of observations and experiments is then expressed in theories whose conclusions again must be checked experimentally, that is, measured through observation and experiment. *There are no physical theories which do not eventually lead to experimentally or observationally verifiable consequences. Therefore, experiment and observation are essential parts of a practical test of a physical theory. In this respect they are a part of social practice, which is the decisive criterion for the truth of scientific knowledge.*

The limits of validity or application of theories and methods can be tested by experiment and observation, before these limits are established by theoretical research. If theoretical research has already determined such limits, they can be tested afterward by experiment and observation. Every comparison of theoretical knowledge with experience presupposes measurements from experiments or observations. Measurements are also a fundamental precondition for mathematization of physical theories. That is why physics was able to emerge only when mathematical methods were incorporated into the experimental methods for the observation of nature.

The obvious advantages offered by experiment for acquiring tested scientific experience must not lead to the underestimation of the importance of systematic observation. Whether the objects of investigation can be subjected to scientific experiment or whether one is limited to systematic observations depends ultimately on the nature of the objects. No one would seriously try to experiment with the universe as a whole or with the solar system. But this does not mean that these objects are not accessible to scientific investigation. Cosmological theories can only be tested with material gained from observation. This accounts for a number of methodological complications. In this field of physical research we can only generalize theoretically what in fact has been found empirically. We are not able to create an experimental situation, although theoretical conclusions from laboratory experiments can be incorporated into the overall theory.

In the process of cognition, use is made of experiment and observation to acquire data to confirm some particular theory, to verify some of its predictions, or simply to lay the basis for the formulation of a theory. In all cases, real objects are utilized and are subjected to the more or less ideal conditions of the experiment or observation. Theory, however, must always work with ideal objects. Mass points do not exist in reality, but they can be simulated with sufficient accuracy, e.g., in the motion of a planet around the sun. Under certain conditions one can treat the real object as an ideal object in the sense of the theory. An encroachment by the subject of cognition upon the objective occurrence arises in this situation, but this is also the case when the subject chooses the conditions of observation and experiment. In one case we are dealing with ideal conditions and in the other case with material conditions. In either case, these conditions have to be taken into account when the limits of validity of our knowledge are determined.

The fact that classical mechanics usually neglects the changeability of macroobjects does not mean that physicists consider these objects absolutely unchangeable. However, under the conditions studied by classical mechanics, they can be viewed as unchangeable. At any rate, physical theories do not exclude objective development. As the thermodynamics of irreversible processes shows, they can even stake out the framework for processes of development. Often, however, it is possible to neglect questions of development in physical problems. But this is not a justification for metaphysical thinking in physics. On the contrary, it is necessary to know the limits within which theory can treat changing objects as unchanging.

Methodologically, we must differentiate among experiment, observation, measurement, and experimental method. The experimental method can become a component part of the methodology of a mathematized natural science only on the basis of measurements. Measurement completes an observation or registers the result of an experiment. Every measurement presupposes a measuring instrument, a situation created by human beings on the basis of the known laws, in which the result of the interaction between measuring instrument and object is established. As a result of the interaction between the measuring instrument and object occurring under well-defined conditions, the results are registered in the form of signals and the interaction thus becomes one part of the behavior of the object. Just as measuring instruments are a specific means for the objectification of scientific knowledge, they are also the expression of the creative activity of the subject of cognition. The creation of certain conditions and their variation exert an active influence on the object of investigation. This interaction contributes to the deeper and more complete understanding of the object. In particular, one can then create such conditions and study such properties and behavior that do not manifest themselves in the same way during the natural existence of the object. This is important in general, for scientific cognition, and, in particular, for the

as well as the interpretation of the results in the light of already existing theories or theories under formulation.

4. Epistemological and Methodological Problems of the Process of Physical Measurement

a. Physical concepts and measure

Every physical measurement employs some measure for physical concepts. The properties of physical objects reflected in the concepts are then expressed in numbers. *The introduction of a measure makes it possible to deal with the quantitative side of physical qualities.* Theoretically, any real number can occur as the measured value. In practice, every measurement has an error, and the measurement process determines the range of real numbers within which the true value of the measured quantity lies.[14]

Here, we will deal only with the establishment of measures. A measure can be introduced by definition through the use of law statements in terms of measures already existing (secondary measures), but without this a direct measure can also be introduced (primary measures).

Primary measures depend on a relation of comparison, i.e., a topologization must already have been carried out. Comparative concepts can generally be described as follows: "x is less . . . than y" or "x is equally . . . as y." Thus, the comparative concept "x is less bright than y" or "x is equally bright as y" differs from the classificatory concept *bright* by the fact that the former makes it possible, in contrast to the latter, to set up a certain ordering in the field of investigation. This advantage of comparative concepts applies to an even greater degree to numerical measures, for which case numbers or sets of numbers can be assigned to an object or a set of objects. Some physical concepts associated with such numerical measures are, for example, temperature, velocity, and volume. An important advantage of numerical measures is that they make possible a differentiation in cases where this is not possible with classificatory or comparative concepts. Hence, the numerical measure for wind speed in meters per second makes possible greater differentiation than can be done with a scale based on twelve wind as well as the interpretation of the results in the light of already existing theories or theories under formulation.

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speeds as determined by the effects of the wind. At the same time, numerical measures allow the same determinations as classificatory and comparative concepts.

The advantages of numerical measures over nonnumerical ones become very clear when law statements are formulated. This is especially the case when a law-governed connection is to be described by three or more variables. An example is the universal gas law. It is known that the volume of a gas is proportional to the temperature and inversely proportional to the pressure. In all cases in which temperature and pressure either increase or decrease simultaneously, one can predict the behavior of all three variables only on the basis of a description of the mutual interconnection of the three variables based on a numerical measure. For example, whether or not the volume increases, remains the same, or decreases depends on whether the temperature increases more rapidly than, the same as, or more slowly than the pressure. As long as there is no procedure available for associating the temperature and the pressure with numerical values, nothing can be said about the change in volume.

In passing from comparative to numerical measures the following factors have to be considered:

1. choice of a form of scale: a decision has to be made about when two intervals on the scale, i.e., two quantitative differences of the given quantity are to be taken as equal or unequal.
2. the position of the zero on the scale: a decision must be made about when a property is to be assigned the value of zero.
3. the choice of a suitable unit: the size of one unit of the physical quantity has to be fixed.

Topologization and the establishment of a measure are the theoretical foundations of measurement. The measurement should be seen as a practical activity for verifying and realizing both conceptions. They have a common logical structure, which is supplemented by decisions on the form of scale, the position of the zero, and the size of the unit.

b. Specific features of the physical measuring process in macrophysics and microphysics

If there is a change in the two interacting physical systems — the object of the measurement and the instrument — during a measurement, then the question arises whether the properties found as a result of the measurement also exist independently of the measurement or have meaning only in connection with the measurement. The experimental data represent statements about the results of the measurement. The properties thus found are then the direct expression of the interaction between the object and the instrument. Therefore, in the general case, the interaction cannot be neglected, and the property observed cannot one-sidedly be assigned to the object in isolation from its relations to other things and phenomena. If this were done, the dialectics of interaction would be dissolved in the totality of correlation-free relations among individual objects and processes. Such a view would ultimately be based on the existence of "objects-in-themselves" as carriers of properties in isolation from all interactions. In this way the material unity of the world would consist of interactions among unchangeable objects, whose properties could change in some definite way without the objects themselves changing. In the final analysis, such a concept of the relationship between object and property amounts to the separation of matter from motion. It is linked with the Aristotelian view of substance and is incompatible with the dialectical-materialist concept of matter. It is no longer the dominant view for the description of physical objects. Our knowledge of physical objects is the result of the investigation of various forms of interaction among objects.

In the process of measurement a special form of interaction is of fundamental significance: The interaction between the measured object and measuring apparatus must also be included among the various types of physical interactions. It cannot be adequately described by the concept "disturbance of object by the measuring apparatus," because this is only one side of a dialectical interrelationship.

The concept *observable* must be introduced into the theory of the measuring process. By *observable* we understand the "totality of determinations about a) an object of measurement, b) a measuring apparatus, c) a prescription about how the measuring apparatus is to be used, and d) a unit of measurement . . . provided that two measurements of the same kind, one immediately following the other, yield the same result with certainty."[15] It is quite clear that we have introduced a theoretical concept. In practice, two successive measurements hardly ever yield the same result with certainty.

The information acquired in the process of measurement must not be viewed independently of the interaction connected with the measuring process. It expresses the connection between the interaction and the properties of an object in a specific way. It indicates the relativity of the properties in relation to the interaction. "That is why one definitely cannot understand by the concept of observable the property of the measured object in isolation from the process of measurement and the measuring apparatus."[16]

These conclusions could only be formulated after physics had penetrated the microworld. The problems of measurement in macrophysics and microphysics, apart from their common features, also have a number of extremely important differences.

A fundamental assumption for the theoretical constructions used in macrophysics is that the phenomena are independent of the conditions of observation. Accordingly, physical phenomena and processes are absolute in the sense that the properties of the object, as established through the measurement, are not, in principle, determined by the means of cognition. A dependence arises only in connection with the reference system, whereby one and the same phenomenon can take on different forms in frames of reference that move relative to one another. Fock remarks: "The physical process was considered something that occurs 'in-itself,' and not as a phenomenon which can be concretely known with the help of certain means of observation. In other words, a phenomenon was related not to an instrument with a certain construction, but at most to a measuring instrument as a whole which moves in a certain way (a certain frame of reference). This usual abstraction in classical physics can be described as absolutizing the concept of the physical process."[17]

This absolutizing of physical processes means that the objects are given properties which they then have absolutely, independently of their interaction with a measuring apparatus, and which cannot be explained and understood on the basis of the theory. Now, the fact is that every theory establishes properties in relation to the objects and connections embraced by it which are neither investigated within the framework of this theory nor explained through reduction to elementary properties and connections. This is what essentially determines the area of application and validity of a theory. To extend our knowledge of the physical world we investigate the relationship between such properties and the physical domain under study by reducing the properties to behavior in interaction.

The more general connections discovered in this way contribute to the unification of the theoretical foundations. A real limitation of such an approach to measurements in macrophysics is the fact that the interaction between measuring instrument and the measured object is not, in principle, considered to be of importance in regard to the properties that are established in this way. We are thus faced by a one-sided view of the relation between interaction and property which absolutizes the latter. From the result of a measurement it can be concluded that this property also belonged to the object before the measurement. The necessary interaction between apparatus and object is considered a disturbance of the actual physical process, and the task of the experimenter is seen to be to keep this disturbance to a minimum.

This can be done in the domain of macrophysics. The disturbances in the measuring process can be considered small if their effect is negligible in comparison with the macrophysical effects under investigation. This is the case in classical physics, as we pointed out in chapter 3. Measurements of Brownian motion by refined techniques have set unsurpassible limits for absolutely exact physical measurements, the theory of which is given by statistical physics. These measurements show that even in macrophysics, two measurements following one another directly do not provide the same result.

From the fact that the effect of an apparatus on the object in macrophysics is practically negligible, one cannot draw the epistemological conclusion that, if Brownian motion is neglected, absolutely sharp measuring values are the only meaningful abstraction for classical physics. Such abstractions cannot be justified by measurements that have been carried out in practice. They can be substantiated only within the framework of a mathematically rigorous formalism of classical physics.[18]

Needless to say, every scientific theory — and this applies also to macrophysics as a whole — is only an approximate reflection of certain domains of objective reality. Within a given assumed scope of validity and applicability it is certainly legitimate and even necessary to neglect effects beyond some order of magnitude. If other appropriate assumptions are made, the same holds for the interaction connected with measurements in macrophysics. However, one cannot then draw general conclusions from such interactions, but only make statements on the basis of the given assumptions.

In chapter 3 we already dealt with the measuring process as an objective interaction between the measuring instrument and the object of the measurement. We pointed out the importance of not neglecting the effect of the instrument on the object. We will now examine these epistemological problems in greater detail.

By comparing the measuring process in macrophysics with that in microphysics, Fock concluded:

> The basis of the new methods of describing the phenomena must take into account the real possibilities of measurement of micro-objects. We must take into account the design and the effect of the measuring instruments, which create the conditions in which the object finds itself. The measuring apparatus and the external conditions must be described classically, moreover, through the specification of their parameters. It is understood that these parameters can be only as exact as the Heisenberg inequalities allow; otherwise we go beyond the real possible limits for the construction of measuring apparatuses.
>
> The necessity of describing atomic objects in a more complicated manner by taking the means of observation (instruments) into account, arises from the fact that we cannot manage here without a mediator. The instruments are the necessary mediators for research on atomic objects. The atomic object only becomes accessible if it interacts with the measuring instrument. . . .
>
> In order to take all this into account it is necessary to take the result of the interaction of the atomic object with the classically described measuring instrument as the basic element constituting the subject matter of the physical theory. On the basis of these interactions one draws conclusions about properties of the atomic object, and the predictions of the theory are formulated as the expectation values for the interaction.[19]

The critical limiting assumptions of macrophysics are no longer contained in this conception of measurement in the realm of quantum physics. Above all, *the measurement is no longer reduced to an external and one-sided effect of the object on the instrument, but is seen as an interaction in a more comprehensive sense, that is, the results are considered to be basic elements of the description of the observed phenomenon, and thus the measurement enters the physical theory as an essential element of it.* From this follows a number of conclusions.

Analysis of typical quantum phenomena shows that there is no justification for the assumption that all properties of physical objects are independent of the measurements made to determine them, as is postulated in macrophysics. In the general case, therefore, this postulate cannot be used for the description of phenomena.

The failure to recognize this was the epistemological basis for the views held for a time by Bohr, Born, Heisenberg, and others that in quantum physics the measurement process involved an "uncontrollable" interaction. In the course of a measurement the essence of this interaction was reduced to an external disturbance of the already existing "motion-in-itself" or of the quiescent system.

The conception that we are presenting here does not exclude the existence of properties specific to the object and independent of the measurement, such as spin, mass, and charge. Apart from such properties, one has to take into account other properties the occurrence of which is conditioned by the measuring arrangement and which do not arise in the object independently of the measurement process. Physical objects are therefore no longer regarded as carriers of absolute properties, independent of every interaction, especially measurement, but some properties first manifest themselves in the measurement interaction. These properties are not the result of "external interference" with the "actual" physical process, but are an essential element of the theoretical description of the observed phenomena.

This means that unlimited divisibility of physical processes can no longer be assumed as it had been in macrophysics. If physical processes and the observed properties of objects depend on the conditions of observation, it can then be assumed that if these are varied, different properties will appear. They are then no longer summarily due to the object and do not remain independent of the given conditions. This is particularly clear when incompatible external conditions are required for the occurrence of different properties. Bohr called this situation *complementarity*. Complementarity expresses the relationship between interaction and property typical of the realm of quantum physics and thus also the relativity of this relationship. Bohr writes:

> In quantum physics, however, evidence about atomic objects obtained by different experimental arrangements exhibits a novel kind of complementary relationship. Indeed, it must be recognized that such evidence which appears contradictory when combination into a single picture is attempted, exhausts all conceivable knowledge about the object. Far from restricting our efforts to put questions to nature in the form of experiments, the notion of *complementarity* simply characterizes the answers we can receive by such inquiry, whenever the interaction between the measuring instruments and the objects forms an integral part of the phenomena.[20]

Bohr's conception of complementarity developed out of a concrete physical situation. Freed from positivist theses, it stresses the significance of the interaction between the measured object and the measuring instrument as an integral part of the phenomena of quantum physics and establishes a basis for the existence of differing, and even contradictory, properties, the connection between them, and their relativity. Although Bohr tried to apply complementarity to areas outside physics, and thus prove its universal validity, it should not be raised to the rank of a philosophical principle without further substantiation and elaboration. The materialist dialectics of Marxist-Leninist philosophy provides a well-tested basis for substantiating the existence and interconnection of contradictory properties.

From the realization that one generally cannot ignore the interaction between the measured object and the measuring instrument in quantum physics in describing the states of microobjects, the question arises whether this interaction erects obstacles to the acquisition of knowledge. This question has played an important role in discussions over the interpretation of quantum mechanics and still has not lost its significance today, even if a number of questions linked to it have been clarified. The philosophical importance of this question arises from the fact that the knowability of the world is an aspect of the basic question of philosophy.

In a discussion of this problem it is important to note that microobjects have specific properties, and that one must not see these in isolation from their material environment and their specific relations and separately from their interactions. Not only does this not set up obstacles to the acquisition of knowledge, but, on the contrary, because it extends the relativity of the reference frame to the means of observation and examination of their specific characteristics, it is possible to grasp objective reality and its dialectical contradictory character more deeply and comprehensively.

The measuring instruments and the external conditions of the measuring process must be described macrophysically. The limits of the real possibilities for the construction of measuring instruments are given by the Heisenberg uncertainty relations. These are not, however, limits on knowledge. What is important here is only that knowledge that goes beyond empirical data can be gained from consideration of the results of the interaction between the macrophysical measuring instrument and the microobject. This does not, of course, contradict the fact that experiment is and will remain the source of new knowledge and new scientific ideas. But a scientific grasp of information in a theory acquired in this way is not merely the direct transformation of experimental data, but a synthesis in which theoretical thinking is very important, and where the active influence of the subject of knowledge on the object of knowledge is assumed and included. The microobject does not become accessible to human knowledge through direct observation, but only through a purposely arranged interaction with the measuring instruments. It is through interactions that properties which are inseparable from the objects manifest themselves. This is why it becomes possible to draw conclusions about them from the observation and analysis of the results of such interactions. An unlimited variety of approaches for investigation of properties from many sides is possible by variation of measuring arrangements and of the associated external conditions in accordance with the specific character of the investigated object.

5. *The Connecting Links among Theory and Experiment, Observation, and Measurement*

The process of acquiring physical knowledge is always a dialectical synthesis of experimentally concrete and theoretically constructive activity. Objective cognition and activity of the subject of cognition are two aspects of one process. Thus, dialectical materialism overcomes the neglect of human activity that was criticized by Engels as typical for the natural science of his time, just as it was for the whole of pre-Marxist materialism. Engels writes: "Natural science, like philosophy, has hitherto entirely neglected the influence of men's activity on their thought; both know only nature on the one hand and thought on the other. But it is precisely *the alteration of nature by men*, not solely nature as such, which is the most essential and immediate basis of human thought, and it is in the measure that man has learned to change nature that his intelligence has increased."[21] The dialectical-materialist theory of cognition does not turn this statement into a purely operationalist interpretation of the process of cognition, but it is the theoretical starting point for the dialectical synthesis of the process of reflection and the result of reflection.

The reflections of objective properties and connections of the object of cognition in scientific concepts, laws and their conditions, and in theories in various stages of development are a dialectical unity of image and project for theory. Hence, they are the result of a completed process of reflection and, at the same time, in the form of constructively projected elements. They always contain the

traces of activity by the subject of cognition. The mechanical-materialist theory of knowledge underestimated the element of projection in the imaging of objective reality. On the other hand, conventionalism and operationalism exaggerate its importance to such an extent that they lose sight of reflection.

The object of cognition, as part of objective reality, is independent of human consciousness. At the same time, by being drawn into the sphere of activity of the subject of cognition, it is not independent of the subject; both reciprocally condition and determine one another. And here the question arises whether human beings are at all capable of recognizing reality "as it is, without alien addition"[22] when, to be able to know it, they must change it.

The experimentally concrete and the theoretically constructive activity of the subject of cognition is not an "alien addition" in the process of cognition, but its necessary precondition for understanding reality as it really is This is the only possibility of avoiding one-sidedness and restrictedness that are features of all epistemological conceptions that downplay the activities of the subject of cognition.

The Marxist-Leninist theory of knowledge does not fall into the error of concentrating so much on the activity of the subject of cognition that it overlooks the objective nature of the result of reflection or places the activity of the subject of cognition outside the sphere of social life that is characterized by production and class relations.

In the Marxist-Leninist theory of knowledge, the object of cognition is considered part of objective reality, independent of human consciousness, and the subject of cognition, as human society, with its historically conditioned level of knowledge. During the process of cognition, the object of cognition, being drawn into the sphere of the subject of cognition, is no longer completely independent of it. This dialectical relation between the object and subject of cognition implies the activity of the subject. But this by no means denies the basic positions of materialism, for the material existence of the object of cognition remains outside and independent of human consciousness. The object is not created by the subject, but knowledge about the object is acquired by the subject.

In the process of cognition there is no straight path from knowledge acquired by observation and experiment to theory, or from an already elaborated theory to knowledge based on tested practical and useful application. We must examine more closely a number of connecting links in this complicated process. Much epistemological and methodological research still has to be done to understand properly these links between the theories and the measurements in observation and experiment. Empirical and rational neopositivist traditions underestimate the importance of this problem, and it is here that the power of materialist dialectics can be displayed.

In this connection, we will consider the role of *models* and *hypotheses* in the process of cognition. They should both be seen as links in the sense described above. However, they differ in their closeness to the methods of mathematical physics. One must also take into account the fact that models and hypotheses are often inseparably connected.

Every model is built around hypothetical elements. Every hypothesis uses idealized objects in one form or another, and thus works with representations also when dealing with the behavior of real objects.

a. Models

Models can be the preliminary stages as well as the objects of scientific theories. They also interpret and illustrate already existing formal theories.[23] *By model we understand an imagined or materialized system which adequately reflects the (ideal or material) object of investigation, or reproduces by analogy the specific properties and relations of the object of investigation.* The model can represent the original, because the investigation of it can bring new knowledge to light about the original.

An *adequate reflection* means the agreement of essential properties and connections of the image with the object being imaged. By reproduction by analogy, we understand the agreement between original and model in certain relations. This can be a structural or functional agreement of various degrees.

This definition makes clear why the concept of model has found a firm place both in the process of cognition as well as in the direct and practical control of technical systems. If one is able to control the model of a major technological complex one can then organize the most efficient operation and servicing without endangering the personnel or the plant. Whatever is to happen in the plant can be simulated beforehand with the model.

Models play a dynamic role in the process of cognition. Models have proved important for the formulation of theories and have often provided the means for understanding complicated processes. The Rutherford model of the atom is a very good example of this.

In the process of cognition, the activity of the subject of cognition also includes the utilization of known law-governed connections to create artificial objects. *Material models* serve as experimental models to replace objects which are not accessible to experimental research or accessible only with great difficulty. It is possible that certain experiments cannot be carried out with the original objects for humane, economic, or other practical reasons (for example, celestial or cosmic objects). In such cases, artificial objects can be made for model experiments, or naturally occurring objects can be used as models that serve as an analogy for the object under investigation.

Ideal models are often used (e.g., mass points) to acquire new knowledge because they are a form of reflection of objective reality in human cognition. Hence, ideal models are the product of active, creative reflection of objective reality by human beings and thus always carry the unmistakable traces of their activity if they also have properties which are not directly discernible in objective reality. However, these properties cannot be designed at will, as the conventionalists claim, but are always chosen in such a way that models with such properties are able to represent the original under certain circumstances. An ideal crystal-lattice structure does not exist, as is implied by the very concept "ideal." Yet many properties of real solid bodies can be explained with the help of a model of ideal structures. And if the model fails, one can approximate it to reality by taking into account certain "errors" in the lattice structure. In the process of cognition the model always stands for the original and can replace it only under fixed circumstances. However, there is no basis for identifying the model with the original.

Many scientists have seen, and made use of, the opportunity of gaining new knowledge through the modeling of objects. Caution here has to be exercised against overdoing this, as in the case of those nineteenth-century physicists who worshipped the ideal of a mechanical explanation of nature based on mechanical materialism. William Thomson (Lord Kelvin) was one of those who claimed that if one could not make a mechanical model of something it could not be understood. It was essentially this attitude that led Faraday to introduce lines of force as an aid in representing electric fields and magnetic fields. Even Maxwell started out with a mechanical model when he began the work that led to his electromagnetic field equations. As helpful as the ideal of a mechanical explanation of nature might have been, we know today how one-sided it was to attempt to reduce physics to mechanics. With this belief in the superiority of a mechanical explanation of the physical world, some physicists at the turn of the century (for example, Poincaré) adopted the epistemological position that science works only with contentless and arbitrarily replaceable pictures. This was the epistemological basis for one particular school in physics which Lenin thoroughly criticized as an abandonment of materialism in his *Materialism and Empirio-criticism.*

Models are no "free creations of the human spirit" as rationalism claims, but they are unthinkable without creative imagination. The method of models presupposes, on the one hand, a "large store of detailed facts and previously used combinations of them, and, on the other, a latitude for reasoning not too closely narrowed by well-known habitual methods."[24] Often a large number of starting or working models are possible and these become narrowed down in the course of the research. In the history of physics it is observed that in practice many physicists make an early decision in favor of a model which later has to be greatly modified or abandoned altogether. The history of physics continually provides examples where it had been believed that an adequate model could be selected with full confidence on the basis of experimental findings, and then it was discovered later, on the basis of new observations and experiments, that it was necessary to return to previously abandoned models, or to search for a combination of several models, as was the case, for example, with the corpuscular and wave theories of light.

Models always reflect only certain aspects of an object of investigation, which, under certain conditions, represent the essence of the phenomenon, but which, under other conditions, do not or no longer describe this essence. As with all other products of cognition, the inexhaustibility of objective reality must at least potentially be taken into account.

As conclusions based on analogy are always made when constructing a model, the conditions under which such conclusions are possible must be investigated. An analogy is a scientifically justified reduction, but it also conceals the danger of reductionism. This is why it is particularly important to analyze carefully the conditions under which the given analogy is justified.

In setting up models or working with them, the following four phases can be distinguished:

1. The construction or formation of a model. Other models can act as forerunners. This phase is closely linked with the formulation of a theory.

2. Testing of certain consequences of the model in thought experiments and laboratory experiments for the improvement of the model and the further development of the theory. In this phase it may prove necessary to replace the original model with a better one or to modify it.

3. Utilization of the model to arrive at conclusions about the behavior of the modeled object.

4. Integration of the model into a comprehensive scientific program of research and comprehensive theoretical analysis within the framework of current scientific views.

The extensive use of models in many scientific fields has led to the rapid development, over the last ten to fifteen years, of mathematical theories of models. The results of these theories are being used in the far-reaching epistemological and methodological discussions of problems connected with the model method.

b. Hypotheses

Hypotheses are scientifically grounded conjectures about a hitherto unknown circumstance. Linked to, but going beyond, confirmed theories and experimental data, they are formulated on a scientifically sound basis and at the same time are a more or less bold thrust into new scientific terrain.

By the beginning of the twentieth century the belief of mechanical materialism that it had found an unshakable theory in classical mechanics was thoroughly shattered. Many philosophers of science and natural scientists, lacking knowledge of the dialectics of the cognitive process, concluded that human beings were unable to acquire reliable knowledge. These theorists fell into epistemological relativism; they said that all knowledge is only hypothetical, that the results of science are hypotheses at best. Even today, such statements can be found in neopositivist philosophy of science, in which it is no longer possible to differentiate between hypothesis and law.

At a time when the physicists still thought mechanical materialism to be a suitable philosophical foundation for physics (insofar as they recognized the need for one at all), dialectical materialism had for some time been paying attention to the examination of the problem of hypotheses and their role in the process of cognition.[25] In our discussion of philosophical generalization as a specific method of cognition, we already indicated the importance of hypotheses for the development of the natural sciences.

More than 100 years ago, Engels wrote:

> The form of development of natural science, in so far as it thinks, is the *hypothesis*. A new fact is observed which makes impossible the previous method of explaining the facts belonging to the same group. From this moment onwards new methods of explanation are required — at first based on only a limited number of facts and observations. Further observational material weeds out these hypotheses, doing away with some and correcting others, until finally the law is established in a pure form. If one should wait until the material for a law was *in a pure form*, it would mean suspending the process of thought in investigation until then and, if only for this reason, the law would never come into being.[26]

In this passage, too, it is clear how important it is to differentiate between hypotheses, which lead to cognition of laws, and the results of the process of cognition — the laws themselves. Engels emphasizes the dialectics of the process of cognition, in which cognition takes place only through the interplay of the experimental and theoretical phases of research. That is why he criticizes empiricism so sharply.

Hypotheses differ from ideal models, which represent the idealized objects of a theory. They are the preliminary or interpretative models of a theory, principally through their function in the process of cognition. They can be preliminary stages for a model, but they can also be formulated within the framework of an ideal model. Hence, models can be the phenomenal form taken by a physical hypothesis. If the hypothesis is confirmed, the model is then no longer hypothetical, but remains as an idealized object of theory.

The following stages of hypothesis formation can be distinguished:

1. Viewing the results of observations and experiments.
2. Setting up one or more hypotheses (working hypotheses) to explain the investigated circumstance. These must stand up to what has been considered to be reliably established, or they can stand in contradiction to such knowledge if, but only if, there is sufficiently strong evidence in their favor.
3. Derivation of all consequences from the hypotheses and verification of these consequences through observation and experiment. Some working hypotheses may have to be given up while others are confirmed. It also happens that the consequences of certain hypotheses cannot be immediately verified due to the current level of experimental technique. This will then often stimulate the development of the appropriate experimental methods.

Hypotheses not only play a mediating role between experiment and theory, but they also belong, in part, directly to the methodological arsenal of theory development. Since the path from measuring data in observation and experiment to theory and vice versa is becoming longer and more complicated in physics, the formation of mathematical structures as a form of hypotheses, followed by theoretical and experimental verification by traditional methods, is becoming increasingly important. Heisenberg once viewed the success of his matrix mechanics as a reason to assign mathematics a function in the process of cognition in physics in a way that carried a danger of underestimating the importance of experiment and observation. For example, discussing elementary particles, he commented that "the smallest units of matter are . . . forms, structures or — in the spirit of Plato — ideas about which one can speak unequivocally only in the language of mathematics."[27] If one were to take seriously his reference to Plato, then cognition would be possible only through contemplation. Experimental data, obtained with great effort at the increasingly powerful accelerators, or the data about the microworld obtained from cosmic rays with increasingly complicated methods, would be almost worthless. Nevertheless, to the very end of his life, Heisenberg remained a physicist who never forgot that physical theories must prove themselves through observation and, above all, experiment. Therefore, we should take his remark as a way of emphasizing the relative autonomy of theoretical research in physics.

6. Mathematical-Theoretical Methods

In the following, we will try to further substantiate the view expressed in our arguments against empiricism that the road from experimental results to theory is neither straight nor automatic. As we have already indicated, we must avoid the metaphysical alternative to empiricism, which transforms the relative autonomy of theory into absolute independence and looks upon observation and experiment simply as a decorative element of physical research.

A most significant contribution of Galileo to research in natural science was his realization of the need for experiment and the use of the mathematical method in the process of cognition. Experiment alone can provide very little knowledge if one does not fit it into the framework of mathematized physical theories.

In chapter 3, examples were given of cases in which the demand for consistency of verifiable statements makes it necessary to conduct a decisive experiment to learn which of two different physical theories is valid if contradictions occur between statements in the two theories. One treats the partly contradictory physical theories like formal theories which cannot both be true, and then seeks to decide from the experiment which of the two is false. This is a way of showing the connection between a mathematical formalism and an experiment in physics. The violation of the principles of formal logic (in this case, noncontradiction) leads to the necessity of new experimental activity. This method is important especially for the systematic exposition of our knowledge in physics. For example, the Michelson-Morley experiment is described in almost all textbook discussions of the theory of relativity as a decisive experiment which forced Einstein to re-examine mechanics. It is doubtlessly correct to state that if Einstein had known the results of that experiment, it would have been an indication to him that mechanics had to be changed. There are, however, well-founded reasons for believing that Einstein did not know the Michelson-Morley experiment when he arrived at the special theory of relativity. As was the case with other physicists before him, he felt that the fact that Maxwell's electrodynamics and classical mechanics were subject to different transformation laws was a serious theoretical problem, and he sought a formulation of electrodynamics and mechanics to which the same transformation group would apply.[28]

For our discussion here, it is not important to know which road Einstein actually took. Both are possible. Historically, the second is more likely than the first. In that case, inner-theoretical considerations would have led to the development of the theory and this, of course, was also connected with experiment and observation. Theoretical research can stimulate the use of mathematical methods for experimental research, but this does not change the fact that experiment and observation are the criteria for the truth of physical knowledge.

It must be stressed here that physical reality is not formed by mathematics. There are various ways of representing physical facts. The validity of each mathematical representation must be established by confirming through experiment that the theories adequately reflect the physical facts. Differing mathematical formulations cannot be excluded. Mathematics is important because, through the construction of systems of ideal objects, whose relations are consistently formulated, we acquire suitable systems of concepts for the representation of real relations. Thus, mathematics expresses the possible relations between ideal objects and can be used to represent real relations. A complicated dialectical process leads from the measured data to the mathematical structures and from the mathematical structures of the theory to experimental confirmation.

In this way various mathematical structures are used to develop physical knowledge, for example, the transition from Newton's equations of motion to relativistic mechanics, and finally, to the equations of motion of quantum mechanics. These structures are subject to the *correspondence principle,* which states that under well-defined conditions the given structures go over into one another. These conditions characterize the range of validity of the given theory.

If we see only the change in the physical theory and its mathematical structure, we quickly reach the epistemologically decisive question: Is there really progress in our objective knowledge? Can the development of physics contribute to better recognition of reality? Do we gain insights into our physical knowledge which reflect objective reality with growing adequacy and take us closer to objective truth, or is the history of physics merely a continual change in theories, and is there no way to determine where they are taking us?

The traditional positivist way of avoiding questions of world view led Thomas S. Kuhn, despite some insights into the dialectics of the process of cognition, to the view that the physical process of cognition is "a process of evolution *from* primitive beginnings — a process whose successive stages are characterized by an increasingly detailed and refined understanding of nature. But nothing that has been said or will be said makes it a process of evolution *toward* anything."[29] We will end our epistemological considerations by examining in which sense the physical process of cognition is also a process of development "toward anything," namely, a process of approaching objective truth.

7. *Progress of Knowledge in Physics*

The continual discovery of hitherto unknown objects and relations during our deeper penetration into the structure of matter again and again leads to changes in the concepts of physics or in some of its fields and to changes in existing theories (restriction or extension of their validity or modification of their fundamental relations) and to new theories. In this connection, the discussion around *truth* is of fundamental importance. A lack of knowledge about the dialectics of the process of cognition can lead to resignation and despair among particularly committed physicists when previously accepted physical ideas break down. For example, Bohr's quantum conditions for the Rutherford model of the atom contradicted classical electrodynamics. Lorentz reacted by asking: "Where is truth if we can make statements about it that exclude each other? Are we at all capable of recognizing the truth, and is there any sense in occupying oneself with science at all? I have lost the conviction that my work has led to any objective truth and I don't know what I lived for; I only regret that I did not die five years ago when everything still seemed clear to me."[30]

This attitude may seem exaggerated to us, but it was shared by many physicists whose mechanistic world view, painstakingly built up during the course of two centuries and proved successful for such a long time, collapsed at the beginning of the twentieth century. Even a physicist like Planck, whose quantum hypothesis was to become one of the pillars of physics in the twentieth century, was deeply concerned about the revolutionary changes in physics.

At a time when the contours of the new physical theories were not clear to most physicists (special relativity theory) or were not yet known (quantum mechanics), Lenin,in his *Materialism and Empirio-criticism*, made a profound analysis of epistemological problems in that phase of the revolutionary changes in physics. There he elaborated the dialectical-materialist theory of truth and showed its significance for research in the physical sciences.

The dialectical-materialist theory of truth draws its conclusions from the materialist answer to the basic question of philosophy for the process of cognition, and it explains dialectically the relationship between the objectivity and relativity of cognition. The acceptance of an objective truth, i.e., the content of human ideas which do "not depend on a subject . . . on a human being or on humanity,"[31] does nothing more than express a fundamentally materialist attitude, according to which our physical theories, hypotheses, and statements are reflections of objective reality. Here, the source of our knowledge is seen as being outside and independent of our consciousness; in agreement with the development of science, the knowability of objective reality is asserted.

For Lenin, accepting objective truth also meant accepting absolute truth. "If we want to advance materialism . . . we must learn to put, and answer, the question of the relation between absolute and relative truth dialectically."[32] *Absolute truth is identical to the exact reflection of objective reality*. This can be achieved only through the potentially infinite chain of relative truths of our knowledge in the individual branches of science, which are not only relative, but have both a relative and an absolute truth content. "Human thought then . . . is capable of giving, and does give, absolute truth, which is compounded of a sum-total of relative truths. Each step in the development of science adds new grains to the sum of absolute truth, but the limits of the truth of each scientific proposition are relative, now expanding, now shrinking with the growth of knowledge."[33] That was Lenin's philosophical generalization of the process of cognition in physical science.

An essential feature of scientific progress is to determine exactly the range of validity of existing knowledge and to formulate new knowledge outside the limited field of validity. For example, Einstein's criticism of the concept of simultaneity made it clear that this property of physical occurrences depends on the given frame of reference, whereas previously one had thought them to be independent of it. Heisenberg's matrix mechanics and Schrödinger's wave mechanics make it impossible to apply the concept of trajectory to microobjects. In Feynmann's formalism of quantum mechanics, it becomes clear why it is pointless to speak of quantum-mechanical "paths" in analogy to classical mechanics. The behavior of a microobject must be described by the totality of all geometrically possible nondifferentiable curves joining two points of observation.

The physical process of cognition brings us closer to objective truth and ultimately converges to absolute truth. The objection of Kuhn and others to this view of truth is, in the final analysis, that we cannot assess the state of our knowledge with respect to absolute truth, because the latter is not at our disposal. There is no doubt that this is correct. No one, neither the philosopher nor the physicist, has access to the absolute truth, and therefore it cannot be used as a yardstick to determine how near physical knowledge has come to absolute truth. However, by means of the criterion of practice — and for physics this includes experiment and observation — we can judge the progress made and thus how much closer we have come to the absolute truth.

The conception that a mathematically formulated unified theory for physics is to be identified with absolute truth leads to an epistemological short circuit. Every such conception (see chapter 2) formulated thus far in the history of physics has been replaced by a more general conception. There is no doubt that these conceptions have had great heuristic significance for the development of physics and will continue so in the future. However, the dialectics of the process of cognition leads one to expect that for every proposal to unify all existing physical theories there exists a still more general one. This prevents the identification of one given mathematical formalism with the absolute truth and avoids the danger of being oblivious to the dialectics of further progress in cognition.

> We must continually keep in mind the fact that: From the standpoint of modern materialism, i.e., Marxism, the *limits* of approximation of our knowledge to objective, absolute truth are historically conditional, but the existence of such truth is *unconditional*, and the fact that we are approaching nearer to it is also unconditional. The contours of the picture are historically conditional, but the fact that this picture depicts an objectively existing model is unconditional. When and under what circumstances we reached, in our knowledge of the essential nature of things, the discovery of alizarin in coal tar or the discovery of electrons in the atom is historically conditional; but that every such discovery is an advance of "absolutely objective knowledge" is unconditional.[34]

Chapter Five
DIALECTICAL MATERIALISM AND BOURGEOIS NATURAL PHILOSOPHY

The critique of bourgeois philosophy is an integral part of Marxist-Leninist philosophy. However, this does not mean brushing it aside and ignoring its existence. On the contrary, a deeper understanding of the essence of bourgeois natural philosophy puts one into a better position to deal critically with the idealist origins of contemporary regressive views. Bourgeois natural philosophy is essentially a set of systems of idealist statements about the philosophical problems of the natural sciences. Its principal features can be examined by considering its main currents, past and present. This can be done if we first note the following points.

The changes in the productive forces naturally affect bourgeois natural philosophy as they do bourgeois ideology as a whole. The needs arising from the development of the productive forces find their reflection in bourgeois ideology. Among the essential factors affecting the development of bourgeois philosophy of science are the increasingly interdisciplinary character of research in the natural sciences and the demands of the scientific and technological revolution. The growing influence of Marxist-Leninist philosophy in the capitalist world has had its consequences. The technological revolution, in particular, is giving rise to a range of complex problems such as those connected with the environment. Discussion of such problems often entails a combination of viewpoints. Comments by futurologists reflect various idealist standpoints, and very often the authors themselves do not see that their views are part of long-known and well-defined currents of bourgeois philosophy. In the capitalist countries the intentions of natural scientists can also turn into their opposite. Culturally pessimistic statements about the future of science and society can sometimes be interpreted as a negation of an originally intended humanistic aim. Such is the case where a bourgeois theorist, worried about the misuse of the developing forces of production, reaches the conclusion that the development of science itself is the evil, and then demands the curtailment of the application of scientific knowledge to production, so as to slow down the destruction of society. In such approaches society as a whole is implicitly identified with bourgeois society.

In bourgeois futurology, moreover, there is a tendency to integrate science in a way that obliterates the distinction between the natural and social sciences as two fundamentally distinct scientific systems, and consequently in the discussions they are implicitly treated as one. For example, the relations between humans and nature are often themselves the subject of discussion, and not just the philosophical problems of an individual field of science. This means that a critique of bourgeois philosophy of natural science, even within a specific field, must always take into account the unity of bourgeois philosophy of natural science and bourgeois ideology. In such a critique bourgeois natural philosophy is not being criticized for its own sake, but as part of the confrontation with bourgeois ideology as a whole. This presupposes a certain understanding of the main currents of bourgeois philosophy of natural science in order to be able to see the basic idealism through the veiled-over application of these ideas. If the critique of bourgeois ideology, and hence of the idealist natural philosophy, is to be well grounded, a number of areas have to be considered.

1. *The materialist view of history is the decisive basic position*, i.e., the Marxist-Leninist assessment of the character of our epoch must be the starting point for an analysis of ideological changes in the capitalist world.

2. *The balance of power in the world is changing in favor of socialism.* The socialist community of states, and the Soviet Union in particular, are increasingly putting their stamp on progress in the world.

3. *Imperialism, in its policies, is forced to take into account the policies of socialism.* It searches for new strategies and is trying to pursue a policy which will mitigate its own contradictions and searches for ideologies that will successfully veil over its imperialist essence and make it appear more attractive. This makes the ideological struggle sharper and more complicated.

4. *Bourgeois ideology, since the beginning of the general crisis of capitalism, is a means of maintaining a historically obsolescent social formation.* The form of the ideology changes with the demands of the time and a qualitative change in the intensity of the effects can be noted within individual areas. These changes must be recognized and analyzed if an assessment of the ideology and its effects is to be given in a specific social area.

1. The Natural Philosophy of Positivism and Neopositivism

Bourgeois philosophers usually illustrate the influence of *positivism* and *neopositivism* on the modern natural sciences with the help of two examples. One is Mach's influence on Einstein in his work on the theory of relativity and the other is the importance of neopositivism for the philosophical interpretation of quantum theory. The Copenhagen school, too, had a positivist orientation for a long time. Many natural scientists understood by positivism only the acceptance of positive knowledge as the basis for the formulation of theories, the emphasis on sense impressions as the starting point for the acquisition of knowledge. They did not see the idealist consequences of positivist views.

Comte introduced the expression *positivism* to describe a philosophical direction in his "Discourse on the Spirit of Positivism" (1844). "In one word," wrote Comte, "the fundamental revolution characterizing the manhood of our spirit is largely to set everywhere in place of the unattainable determination of the actual causes, simple research for laws, i.e., the constant relations existing among the observed phenomena."[1]

This was directed against metaphysics, understood as the search for ultimate causes for the ultimate source of the world and, therefore, against speculative natural philosophy. It was also directed against the philosophical analysis of scientific knowledge aimed at answering fundamental questions of world view. The former is usually welcomed by natural scientists. The latter is not usually seen in all its consequences, but becomes clear if one remembers the demand by positivism that one should cease looking for causes at all.

Comte demanded that the word "cause" disappear from philosophical terminology, because it is "irrational" and "sophist." It is true that one cannot investigate original causes. What is accessible to scientific study is only the laws that are currently operative. This goes far beyond emphasis on the senses for gaining knowledge. There is no doubt that the senses are the source of our knowledge in all processes of cognition. We build our concepts on them. It is with their help that we check the correctness of our theoretical conclusions. If, however, we eliminate the word *cause*, i.e., if we deny the possibility of finding causes, then the laws we study only deal with our senses and their connections, and are no longer the reflection of objective relations. The connection between relations which exist among observed phenomena and those that exist objectively, whether or not they are observed, is negated. The question to be answered is: Do the relations, such as those between various elementary objects, exist objectively or not?

This is one of the most important epistemological questions that comes up repeatedly when new discoveries are made in the natural sciences. The point here is that the cause of our perceptions is objective reality, which exists outside and independently of our consciousness. It is objective reality which makes sensation and perception possible through its action on our senses and conveys to us information about the external world. We are thus back to the old epistemological question: Can we acquire knowledge about objective reality through reflection of sensations? Positivists treat this problem as a meaningless question which goes beyond what we can know. They support this position by asserting the impossibility of finding causes of things. If we cannot ever find the original causes of material processes, then it is pointless to search for the original cause of our perception. Hence, questions about objective reality, about matter as the totality of objectively real things, phenomena, connections, etc., which can be reflected by our consciousness, become meaningless questions.

It is not the emphasis on perception as the source of our knowledge that is idealist, but the positivist denial of the cause of our perceptions, that is, objective reality. The difficulty in refuting the positivist views is that the main problem is not always put forth clearly. This is an important problem in the work of the physicist. For example, the discovery of a connection between wave and corpuscular properties in elementary objects raised epistemological problems which are directly connected to those brought up by positivism. Heisenberg noted "that one would get into hopeless difficulties if one tried to describe what happens between two consecutive observations."[2] In the probability statements of quantum mechanics the precise course of a physical process is not described. Only the result of it is predicted, and only as a probability. That is why Heisenberg is correct when he says that one cannot unequivocally reconstruct the course of a process out of the statistical laws. In neopositivism, however, this is linked with the general statement that only statements about what has been observed are permissible. However, this limits the significance of theories which predict experimental data yet to be found. Here we see the effects of the restrictions positivists place on questions to be answered by science. *Positivism conceals the weaknesses of physical theories by not permitting questions about the causes of specific phenomena.* In the case of philosophy, positivism excludes all questions about objective reality, and in the individual sciences, questions about what exists between the various observations, or the nature of the concrete objective laws applicable to the objects under investigation.

The purpose of science is not to study the behavior of one particular object. For example, the point is not to explain why a certain uranium atom decays at a particular time, but to investigate the decay laws more deeply and to develop a theory of elementary particles. That is why the laws of elementary particle behavior are being studied today; that is why the hypotheses about existing fundamental particles are being tested; and that is why the relation between structure and elementariness is under scrutiny. The results of elementary particle physics do not replace the basic statements of quantum theory, but allow them to be better understood. It is interesting to note that Heisenberg dealt critically with positivism at a time when he was trying to find a unified theory of elementary particles.

The main theses of the positivist views are:

1. *The source of all human knowledge is that which is positively given.* This includes the observable, the experimental results, the instrument readout, and, in the end, the concrete sensuous perception which tells us something about a process in objective reality. Anything which goes completely outside of perception cannot be the subject matter of our knowledge.

2. *Both the world around us and the human subject are a unity of complexes of sensations of sense elements.* There are no basic differences between subject and object, physical and mental, matter

and consciousness. Here, the unity of the world is sought idealistically in the ideal — the primacy of matter is rejected.

3. *Questions about what lies behind the senses are meaningless questions. Positivism tries to stand above materialism and idealism, but by denying materialism it becomes completely idealist.*

The essence of the positivist view is *subjective idealism*, because it denies the existence of objective reality, or more precisely, it views this existence as unprovable and declares the subjectively conditioned perceptions to be the source of our knowledge. This subjective idealism does not, however, characterize the approach of natural scientists to their work. Many of them accept only the emphasis on that which is positively given and thus oppose pointless speculation. This also explains the constant vacillation of some natural scientists between idealist and materialist formulations of their views about science. On the one hand, along with the positive attitude that they think they obtain from positivism, they also accept idealist conceptual formulations. On the other hand, they object to being called subjective idealists, which is understandable because they are basically spontaneous materialists.

Neopositivism deals primarily with logical investigations. Stress is placed on the meaning of certain questions. Mach, too, wrote about this: "The question which is often asked, whether the world is real or whether we merely dream it, is devoid of all scientific meaning. Even the wildest dream is as much a fact as any other."[3] Mach obviously mixes two problems. A dream-fantasy is, of course, a fact in the sense that it exists. But when we ask about reality, the important thing is not *whether* it exists, but *how* it exists. The *how* is answered in the most general sense when one answers the basic philosophical question about the relation of thinking and being. Accepting matter as primary means accepting the existence of reality, i.e., that something exists outside and independently of our consciousness and is reflected by it. Dreams, too, provide images of objective reality, but in a distorted form. The existence of dreams does not make the question about the existence of objective reality pointless. After all, we can test against reality the correctness or incorrectness of the images in our dreams.

Neopositivism (logical positivism) sets philosophy the task of clarifying the meaning of statements. The starting point of logical positivism was the Vienna Circle around Schlick, who held Mach's chair in Vienna after 1922. Together with Reichenbach (the Berlin Circle), Carnap founded the journal *Erkenntnis* (1930). The ideas of the Vienna Circle were carried far into the ranks of natural scientists through personal discussions, international congresses, and publications. Schlick's death and the flight of many scholars from fascism led to the dissolution of the Vienna Circle. New centers arose in the United States (Reichenbach, Carnap, Feigl) and England (Waisman, Ayer). Carnap formulated the tasks of the Vienna Circle in the following way: "The work of the Vienna Circle . . . is aimed at science which is investigated either as a whole or in its individual branches; the concepts, statements, proofs, and theories appearing in the various fields of science are analyzed, and, what is more . . . from the logical viewpoint . . . . By science we understand the totality of the accepted statements."[4]

The main goal is thus the logical investigation of statements in the individual branches of science, i.e., of their extensional relations. It was precisely the goal of the Vienna Circle that struck a responsive chord among the physicists. The experiences connected with the discovery of the theory of relativity showed that at certain stages of scientific development, fundamental concepts change their content. They must be critically examined and refined. Einstein did this, principally, with the concepts of space and time. In doing so he based himself largely on Mach's critique of the classical space-time concept. He had already pointed out that the world of space-time can exist only in connection with masses and energies. Infeld, too, emphasized Mach's significance: "Although Mach is today quite rightly condemned as an idealist philosopher, there is no doubt that his special *physical* analysis of mechanics played a role in the development that led to the theory of relativity."[5]

Mach and neopositivism linked the essential subjective-idealist conception of positivism with the criticism of certain concepts, a criticism accepted by the natural scientists. Because they accepted the need for criticism, many scientists, including Einstein, also accepted some of the positivist ideas. However, the scientists should not be faulted unduly, as has often been the case with Einstein, since they are not primarily philosophers. It was said that Einstein's philosophy was "inspired by idealism." It is obvious that Mach's criticism of the classical view of space and time and his emphasis on the relativity of space and time influenced Einstein in his development of the theory of relativity. However, physical analysis must not be confused with the positivist-idealist position, which Lenin called a betrayal of science.[6]

A similar situation arose with development of quantum theory. Fundamental concepts such as motion and determinism had to be revised. A thorough analysis was needed before they could be applied to modern physics. This increased the physicists' interest in epistemological problems which arose during such analyses, and also in the logical foundations of the analysis of such concepts. Representatives of positivist philosophy contributed toward clarifying such logical foundations (Carnap), but there were many epistemological problems that they could not solve.

Many natural scientists recognized the importance of Mach's physical analysis of concepts of space and time, although they warned against Mach's idealist conclusions. The well-known physicist Sommerfeld wrote: "Mach's teaching removes all metaphysical prejudices, all traditional dogmatic obstacles which hinder free research. But does it not go too far, does it not undermine that foundation indispensable for a natural scientist, the conviction of the objectivity and unchangeability of the laws of nature?"[7]

In regard to the objectivity of the laws of nature, Sommerfeld, like Einstein and other physicists, too, raised a crucial point in his criticism of Mach's philosophy, although the comments about unchangeability could have been more closely examined, because the laws of nature, too, have a historical character. Einstein's later philosophical position in the discussion around the interpretation of the quantum theory reflected his rejection of idealism: "I still believe in the possibility of a model of reality — that is to say, of a theory which represents things themselves and not merely the probability of their occurrence."[8]

For Einstein, von Laue, and others, the question was one of taking a fundamentally materialist position, but, as Heisenberg stressed, the focus was on the question of whether the Copenhagen interpretation did not make possible an unambiguous and objective description of physical facts without bringing in probability theory.[9]

Heisenberg's answer to this question revealed the real difficulty in the interpretation of the quantum theory. He wrote: "The demand to 'describe what happens' in the quantum-theoretical process between two successive observations is a contradiction *in adjecto*, since the word 'describe' refers to the use of classical concepts, while these concepts cannot be applied in the space between the observations; they can only be applied at the points of observation."[10]

Later, Heisenberg dissociated himself from positivism, which shows that he was not interested primarily in confronting the basic question of philosophy, but that he was concerned with special epistemological problems linked to it. Heisenberg claimed that one could not describe what happens between the observations. Taken by itself, this thesis corresponds to the positivism of Comte and Mach, and also to neopositivism, insofar as it was represented by

the Vienna Circle. Heisenberg elaborated his view by saying that only classical concepts can be used for the description of things, but that classical concepts were not applicable to an unobserved quantum-theoretical process.

This argument contains a serious error. It implies that we can grasp reality only in terms of classical concepts. But this is not the case. Philosophical arguments against this view were already made in the classics of Marxism-Leninism in connection with the criticism of mechanical materialism. These arguments have since been confirmed by quantum mechanics, a field which had not yet been investigated. But the problems raised remain under discussion: Can one deal with the path of an individual particle only statistically, or are there some "hidden parameters" yet to be found? From the viewpoint of philosophy an answer can, in principle, be supplied by dialectical determinism (chapters 3 and 4). A return to mechanistic conceptions seems very unlikely today. The philosophical answer to the physical problem that needs further investigation leaves many possibilities open. *What is definitely excluded, however, is a positivist interpretation of the results of modern physics.* Positivism did not clarify anything; it simply confused the issues. The development of physics on the one hand and the discussions among the Marxists on the other has contributed to further clarity on the matter.

2. The Natural Philosophy of Neo-Thomism and Critical Realism

In Europe, where Marxist-Leninist political parties are the leading political and ideological force in a number of countries and are a growing influence in others, bourgeois ideology cannot deal with Marxist-Leninist philosophy as it often has tried to do — by ignoring it. In those countries of Western Europe in which there exist leading bourgeois political parties with an explicit religious orientation, such as the Christian Democratic Union in the Federal Republic of Germany, very active polemics and ideological struggles are waged against the influence of Marxist-Leninist philosophy. Because of the important position of scientific activity in these countries and the fact that such activity breeds a spontaneous materialism, considerable effort is made to ensure that this spontaneous materialism does not become transformed into dialectical materialism. It is therefore not surprising to find attempts to unite theological doctrines explicitly with a suitable philosophy of natural science.

Toward the end of the last century there arose in Germany a philosophical trend known as *critical realism* (in a certain sense related to, but not directly connected with, the trend in the United States bearing the same name). While not the most fashionable current today among the professional philosophers of science in the capitalist world, the influence of critical realism is strong in the educational systems responsible for the training of natural scientists, engineers, and technicians in a number of capitalist countries, especially in the Federal Republic of Germany. For this reason, the authors of the present book, in preparing the original edition for use in the education of teachers in the physical sciences in the German Democratic Republic, considered the fusion of neo-Thomism and critical realism to be a subject requiring detailed analysis.

Although little attention is given to this particular form of philosophical realism in English-language literature, there has been a growing tendency among scientists, in face of the declining influence of positivism, to identify with some form of philosophical realism. No one particular school, however, can be singled out as dominant. In this situation, the discussion of neo-Thomism and critical realism which concludes the chapter can serve to focus attention on those aspects of philosophical realism that most clearly lead away from a scientific, materialist outlook. At the same time the reader should be aware that the term *realism* has been applied to a wide variety of approaches, some that are very close to a consistent materialism, and others that are almost indistinguishable from subjective idealism. For this reason some additional introductory comment about philosophical realism could be useful to the reader unfamiliar with the subject.

Unlike logical positivism, which was systematically developed by the group of philosophers around the Vienna Circle, realism has no one dominant form. In 1920, a group of philosophers in the United States attempted an organized opposition to positivism, and seven of them issued a manifesto under the title, *Essays in Critical Realism*.[11] However, the group did not hold together in the manner of the Vienna Circle. New varieties of philosophical realism continued to appear. The decline of positivism stimulated further activity in this general direction. As examples of the various trends, one can cite *representative realism, perspective realism, physical realism, structural realism,* and *transcendental realism*. A list several times as long can readily be compiled.

Realism arose in the medieval period as a scholastic philosophy, according to which universals exist outside and independent of human consciousness and prior to the existence of particular things. Realism was contrasted with *nominalism*, which gave priority not to the existence of universals, but to the existence of particular things.

In its modern forms, the common element in realism, insofar as one can be stated, is the acceptance of an objectively existing external world, but generally without any determination of the connections among all things whose existence is recognized. While philosophical materialism asserts the primacy of matter as the source of all existence, philosophical realism can allow for material and nonmaterial forms of being without the primacy of matter. Thus realism can form the basis of a religious world view or an intrinsically atheistic one. But insofar as it does not recognize the primacy of matter, realism retains an essentially idealist content.

Some forms of realism can come close to dialectical materialism. For example, in *A Realist Theory of Science*, Roy Bhaskar stresses the interconnectedness of things.[12] His realism, which he calls *transcendental realism*, asserts the existence of *things* and *mechanisms*, both independent of our consciousness. He fails, however, to elaborate the concept of matter, or even of *thing*. Although he occasionally uses the term matter, Bhaskar avoids discussion of it as a fundamental category, and, as a result, his mechanisms are, in fact, deprived of an object. The failure to deal explicitly with the category of matter inevitably leads him to project possible limits on scientific knowledge. For example, Bhaskar writes, "It seems to me there is no reason in principle why there should not be strata of fields (of perhaps radically different kinds), forever unknown to us. It should be noted that only the identification, not the existence, of fields depends upon the existence of material things in general."[13] Bhaskar's acceptance of *nonmaterial* fields clearly leads to their ultimate unknowability and is an example of the idealist element of his realism.

Realist philosophies of natural science often deny their idealist character. In fact, it is not uncommon in the United States for realist philosophies to see themselves as alternatives to idealism and positivism, whereby materialism is usually ignored. Thus Holden and Roller write:

> Perhaps most people would defend the position that the experiences which come through their senses are directly occasioned by and correspond exactly to an external world, a "real" world which exists regardless of our interpretations. This view is called *realism*, and it is in opposition to two major philosophical systems (among a host of others): *idealism*, which maintains that our ideas and impressions are the only realities, and that we use those to construct convenient concepts such as chairs, meter sticks, and laboratories; and *positivism*, which does not speak of such "realities" at all, excludes speculation upon ultimate causes or origins, and regards nothing as ascertainable or meaningful beyond sense data (for example, pointer readings) and concepts that are referable to sense data.[14]

Another way of disposing of materialism is to subsume it under another philosophical direction. Thus Feibelman writes: "There are three philosophies: idealism, realism, and nominalism; and it is nominalism that properly divides into two philosophies. These are: materialism and subjective idealism. Materialism . . . states that reality belongs to atoms in motion and the void. The mind and all mental things, are, according to materialism, epiphenomenal."[15] Here we have a rather common example of equating all materialism with mechanical materialism. We can point out, however, that, contrary to Feibelman, the dialectical-materialist concept of the mind as an activity of the thinking brain is quite another thing than the reduction of mental process to the physics and chemistry of the brain, or to the motion of atoms, and the consequent characterization of the mind as epiphenomenal. In a somewhat similar vein, we have the realist philosopher Hilary Putnam writing:

> To prevent misunderstandings, let me say that by realism I do not mean materialism. . . . A consistent realist has to be realistic not only about the existence of material objects in the customary sense, but also has to be realistic about the objectivity of mathematical necessity and mathematical possibility (or equivalently about the existence of mathematical objects and about entities which are neither material objects nor mathematical objects — in particular, fields and physical magnitudes.[16]

Putnam is incorrect when he implies that materialism denies the reality of fields, as we have already seen in the earlier chapters. In fact, dialectical materialism views fields as a form of matter. The dialectical-materialist concept of physical properties, as objectively existing properties, has also been discussed in the previous chapters.

On occasion one can find also instances in which dialectical materialists identify themselves as realists on the grounds that the common element among realists is their acceptance of an objectively existing world, a concept which does not necessarily exclude the acceptance of the primacy of matter. The usefulness of such an identification can be questioned for the following reasons. Historically, realism developed as a trend in idealist philosophy. In current philosophical practice, realist philosophies are generally characterized by their failure to establish, in a consistently materialist way, the connections among all things, the existence of which is recognized by the individual realist ontologies (matter, ideas, events, mechanisms, etc.). In fact, even some forms of positivism have been called realism. This question of terminology was already raised in his time by Lenin. Referring to the use of the term realism by one writer, Lenin noted that "the term realism is here employed as the antithesis of idealism. Following Engels, I use *only* the term materialism in this sense, and consider it the sole correct terminology, especially since the term 'realism' has been bedraggled by the positivist and other muddleheads who oscillate between materialism and idealism."[17]

Finally, we note in connection with the discussion that follows that the two leading post-World War II polemics against Marxist-Leninist philosophy have been written by the neo-Thomist Gustav Wetter and the realist Karl Popper.[18]

After the failings of the positivist interpretation of modern physics became clear, many natural scientists turned away from its ideas. Idealist currents that criticized positivism gained influence among natural scientists. *Critical realism,* a form of *neo-Thomism,* is one of the principal currents of this type.

Neo-Thomism is based on the philosophy of Thomas Aquinas (1225?-1274), who maintained that pursuit of wisdom was important for revelation. He said that knowledge of the world follows from the effects of material things on our sense organs. Knowledge of nonmaterial things, however, is acquired with the help of analogies. These analogies indicate a higher form of knowledge, namely, revelation. It provides knowledge of the existence of God. In the encyclical "Aeterni Patris" (1879) Pope Leo XIII set the task of reviving this philosophy in order to use it as an ideological weapon against non-Catholic philosophical currents, especially Marxist philosophy.

Neo-Thomism assumes the validity of religious dogma and uses the natural sciences to substantiate it. The natural sciences, it says, do not prove the existence of God, but through analogies and gaps in knowledge indicate the necessity of faith and the existence of God. It is in this sense that Dolch commented: "One cannot keep God secret, one can only disguise Him. . . . As long as laws of nature were seen as being strictly causal, there did not seem to be any room for God's influence in this world, but as one now believes that world events as a whole are acausal, as is known from atomic physics, there now appears room again for God's influence."[19] Dolch also claims that "the inner preoccupation of modern natural sciences is by no means a formal rebellion against the rule of God (or its proclamation by the Church)."[20] Heim, however, warns against a too-complete dependence on natural science as a theological argument for the existence of God: "As grateful as we are that, according to the witness of a leading researcher . . . , the natural sciences have reached a stage in which Bavink could write the heading: 'Natural Science on the Road to Religion,' we have the feeling right from the beginning that this apologetic method puts us into a state of complete dependence on the current level of the natural sciences. . . . This dependence on the level of the natural sciences could become very dangerous if the wind changes and faith would once again be forced to struggle with the greatest of effort against the wind."[21]

That is why the neo-Thomists continually point to analogy as proof for the existence of God. Hence, in seeking the unmoved mover they argue for the necessity of a nonmaterial first cause and see God as the first necessity and highest principle in the world. They implicitly conclude that the world is necessarily incomplete and finite, and therefore it needs a foundation in a nonmaterial principle. Neo-Thomism finds the epistemological foundation for the necessity of analogy in critical realism, which we shall discuss shortly.

The inclusion of the natural sciences in the substantiation of Thomist philosophy requires an idealist distortion of the objective total connection. Possibility and reality, chance and necessity, causality and interaction are torn apart. According to this view, they are due to differing objects. The prime mover or first cause is assumed as an analogy to the movement of one thing being caused by another, the cause of the one by the other.

The essence of neo-Thomism consists in an objective-idealist apologetic attitude to assumed dogmas which culminate in the claim of the existence of God.

In order to win natural scientists over to neo-Thomism and wage a battle against Marxist-Leninist philosophy, neo-Thomism links up with *critical realism*. According to the assumptions of Thomist philosophy, the existence of God is beyond discussion. In the neo-Thomist analysis, knowledge of natural science is rooted in a non-material world, in a perfect, transcendental being. In order to win the natural scientist over to such ideas it is, however, necessary to present a philosophical interpretation of the results of the natural sciences which allows for the fundamental unknowability of certain areas of objective reality. These unsolvable problems are to convince the natural scientist that they can be solved with the help of religion, i.e., with Thomist philosophy. This philosophy proclaims revelation to be an epistemological method. Revealed knowledge must be believed. For the neo-Thomists the epistemological task set by critical realism is to lead the natural scientist from knowledge to faith, from scientific methods to revelation.

Critical realism, however, is not necessarily linked to neo-Thomism. It also exists as an independent philosophical system, which was developed as a conscious opposition to positivism. It played a major role in helping many scientists to reject positivist positions. Critical realism developed into a school at the end of the last century. Among its founders are Fechner, Lotze, Wundt, and Külpe. Further well-known representatives of critical realism are Becher, Hartmann, Driesch, Messer, Bavink, and Wenzl, although they differ greatly in their views on individual philosophical problems.

These are not the only ones with a critical-realist approach. Among the neo-Thomists, most natural philosophers call themselves critical realists. In both groups, the essential issue is to take the limits of cognition of nature beyond those set by the positivists, and to recognize the necessity of observation when considering the essence of being.

The starting points differ. The critical realists are not committed to accepting religion, let alone a particular religion. The critical realists among the neo-Thomists, however, are bound by the postulates of their religion. Hence, their way of philosophizing differs. The critical realists base themselves on the natural sciences. Objectively, they prepare the way for the theological interpretation of the natural sciences, even if this is not intentional. This group usually

claims to represent a new philosophy, differing both from positivism and speculative natural philosophy. The neo-Thomists, however, use critical realism as an epistemological consolidation of their idealist-religious world view. The individual representatives of neo-Thomism, however, start out from different assumptions — what they are is often determined by the natural science with which they are most familiar. The goals they wish to achieve are often difficult, and sometimes even impossible, to recognize. While some, because of their Catholic belief, search for a way to connect natural science with religion and are convinced they have found this in critical realism, others try at all costs to place the natural sciences at the service of the Church. Scientists such as van Steenbergen, de Vries, and Nink fall between both groups, and the Jesuit Büchel linked his neo-Thomism and critical realism through them.

One certainly cannot claim that only a few neo-Thomist natural philosophers support critical realism. The connection is general. Neo-Thomism must take into account social development and thus the development of the productive forces. The great importance of the natural sciences for scientific and technological progress, and hence for the development of the material basis of society, requires that the road to further progress must not be blocked. For the neo-Thomists it is necessary to produce effective interpretations which prevent modern natural science from refuting neo-Thomism. The development of science has caused natural scientists to turn away from positivism and neo-Kantianism, and has led them back to spontaneous materialism, which they try to comprehend philosophically. Critical realism appears promising as a philosophy which prevents natural scientists from completely accepting materialism. Therefore, critical realism has been officially recognized as the philosophical conception of neo-Thomism.

Pope Pius XII called for an alliance between the natural sciences and critical realism, although his concept of critical realism was broader than that of the critical-realist school: "We would be more in favor of the natural sciences achieving a total view of the visible world in continual contact with a philosophy of critical realism as it could be found among the best representatives of perennial philosophy, which could in some way satisfy the search and burning desire for truth." But Pius XII also issued the following admonition to the neo-Thomist critical realists and natural scientists in general: "May they advance science with all their power, but may they beware of going beyond the borders that we have reached, in order to defend the faith and the Catholic teaching."[22]

This admonition was taken seriously by neo-Thomists, such as

Wetter and Karisch, who have candidly tried to make natural scientists aware of the difference between materialism and critical realism and to interpret their spontaneously materialist attitude not as materialism, but as a realism directed against materialism.

Neo-Thomism is objective idealism. It recognizes a world that is independent of human beings, but subject to investigation. The source of this world is God. This is why it is opposed to positivism, which considers questions about the objective, real existence of things as meaningless; moreover, positivism is fundamentally atheistic. Critical realism, because it denies the possibility of acquiring adequate (see footnote p. 66) knowledge, turns the question of the material of ideal origin of things into a different question the answer to which lies outside the grasp of science.

The conflict between natural science and religion can only be eliminated within an idealist structure. The Vatican Council II deals with the matter as follows: "The Council thus accepts the teaching of the Vatican Council I that there exists a 'two-fold order of knowledge,' two orders separated from each other: that of faith and that of reason, and the Church definitely does not reject the idea 'that the human arts and sciences, each in their own sphere . . . make use of their own principles and methods.' Therefore, in recognition of this 'just freedom' it affirms the legitimate autonomy of culture and above all of the sciences."[23] The teachings of Aquinas about the dual truth, integrating the truth of the sciences into the truth of revelation, help legitimize the development of the natural sciences, without any religious positions being given up. Science is expressly characterized as one order which exists alongside another order, and this other order is not subject to examination by the methods of science. Epistemologically, such teaching leads right to critical realism, which, by claiming that the gaps in knowledge are impossible to fill, leaves room for revelation.

Some proponents of critical realism try to deny the objective-idealist character of this philosophy or its connections with neo-Thomism. Thus Wenzl argues that

> to describe it as an objective-idealist school close to neo-Thomism and to accuse it of tendencies to subordinate knowledge to faith shows a complete misunderstanding of its real essence, which is clearly and unambiguously expressed in its name: it recognizes the existence of an external reality outside of our consciousness which we can perceive and where relations and changes can be largely explained by tested and confirmed hypotheses — hence the name "realism"; however, it does not treat the sensuous qualities, the characteristics of our perceptions, and accepted spatial and temporal relations as objective statements about the things-in-themselves, but merely assumes that the properties and relations which we perceive and attribute to them with good reason correspond to this objective reality and that our knowledge has limits — therefore, the term "critical" realism.[24]

Wenzl thinks that he has found a third road between materialism and idealism. However, as long as he sees reality as merely being independent of our consciousness, but does not emphasize its material nature, his position remains one of objective idealism. He tries to evade the consequences of objective idealism by borrowing from materialism, but in this he is inconsistent.

How little the epistemological basis of neo-Thomism and critical realism differ will become clear as we turn to the fundamental positions of critical realism.

Critical realism recognizes the objective origin of the world. It exists outside our consciousness. Becher writes: "We must recognize an external world outside of the consciousness of humans and animals as real, otherwise the assumption of law-governedness is unsupportable and the sensuous perceptions would lack the causes which they must have according to the causality principle."[25] Here, we can see how Becher capitalizes on one of the greatest weaknesses in positivism. Positivism could not explain the origins of our perceptions and therefore brushed this aside as a meaningless question. Critical realism appeals to the spontaneous materialism of the natural scientist by accepting a real external world.

But the mere recognition of an external world is not sufficient to arrive at the essence of the philosophical issue. The point is the objective nature of this external world, i.e., its independence of human (and a postulated extra-human) consciousness, the material nature of the external world, the primary character of matter over consciousness. But, according to Becher, natural science cannot help us recognize this character. It is here that critical realism sets the boundaries for our ability to acquire knowledge of nature. "Our knowledge of nature grasps only 'formal' features of the external world as such, i.e., only those features which more or less concern its forms, e.g., differences, temporal and numerical properties, and the laws embracing them. Only the form of the external world is accessible to our knowledge of nature, and not its inner properties, its 'inner essence.' That establishes the limits to our knowledge of nature."[26]

Critical realism recognizes a world existing outside of the human being. Hence, it is realism. However, the essence of this external world is not knowable. That is its "critical" element. But this is exactly what makes it interesting for neo-Thomism. Without actually speaking directly of God, this viewpoint provides the possibility for a theological interpretation of the natural sciences. If the limits to our knowledge of nature do not allow us to penetrate the essence of reality, which for the critical realists can be an ideal reality, then this ideal reality can be the work of a world spirit, of an objective will, or God.

This realism recognizes reality in form, but its critical character suggests the apparent impossibility of acquiring knowledge of the essence of this reality, in order that the character of the external world can, in an objective-idealist way, be made ideal. This shows that critical realism, despite its claims to the contrary, is a form of idealism.

Critical realism, although not bound to any religion, leads to a position that forces the natural sciences to turn toward religion. Bavink already had discussed the path from natural science to religion. Wenzl follows this up and writes: "What Bavink means and what must actually be said is that, first, unlike a generation ago, let alone half a century ago, the natural sciences are no longer an obstacle toward a positive religious decision, and that, this assumed, the findings which are obtained without religious assumptions do not make unbridgeable the gap between science and religion."[27]

Wenzl also describes how natural science is to take the path to religion. It "became conscious of its limitations itself" and leads to questions "to which metaphysics . . . can dare give hypothetical answers, even if ultimately they can only be answered through a religious decision."[28]

On the other hand, Wenzl objects to the claim that critical realism tries to interpret the natural sciences theologically. He is of course right when he points out that Hartmann rejected religion, and that Becher and Bavink did not want the natural sciences to be understood as a substitute for religion. But no one had made this claim. The claim is merely that critical realism, with a few exceptions, gives theoretical support to Bavink's idea that natural science is on the road to religion.

While neo-Thomism is bound to the dogmatic acceptance of Thomist philosophy, critical realism strives to set forth questions that cannot be answered by the natural sciences. In the view of the critical realists, this is where religion must enter. The criticism of subjective idealism serves to smooth the path for objective idealism. But the critical realists emphasize that their goal is not

purely and simply to establish a basis for religion. Typical for critical realism is the conscious support of metaphysics.

For the critical realists, metaphysics is ultimately the attempt to found a world view on an idealist basis, one that takes into account the total knowledge of our period, which answers the ultimate questions about the essence of the world in such a way that it satisfies our temperament, our feelings, and our thinking. This metaphysics calls itself *inductive* because it tries to take all experience and scientific knowledge into account. While the effort is there, the assumptions lead to idealist conclusions. Another idealist feature that enters is a vitalistic explanation of the relation between body and soul based on a super-entity principle, according to which the spiritual plays the leading role in all occurrences.

Here again we see that neo-Thomism and critical realism have in common the recognition of an external world the character of which is ideal. They are united in their idealism. Furthermore, the neo-Thomists try to eliminate the basic question of philosophy as a criterion for differentiating between a scientific and an unscientific philosophy. Wetter writes:

> The whole discussion has really nothing to do with the antithesis between idealism and materialism; the issue lies, rather, between an idealist or positivistic epistemology and a realistic one. Throughout we can discern the efforts of Soviet philosophy to counter certain idealistic and positivistic tendencies in the interpretation of quantum physics. We must merely be on guard against the misuse of the concept of "materialism," customarily practised in this context, in that here too the concept of "materialism" is confused with that of "realism." When it is argued that the micro-particle represents a reality existing independently of the process of observation and measurement, this is not a "materialistic" interpretation, but a "realistic" one. The acknowledgement of a reality independent of the knowing subject is not "materialism," since this does nothing to settle the question as to the nature of this reality, i.e., as to whether matter is the only and ultimate reality.[29]

Here it is obvious that Wetter is attacking dialectical materialism and evading the clear lines of battle between idealism and materialism. It is not just an unimportant difference of opinion. The issue at stake is materialism, the acceptance of matter as primary, and therefore the scientific or unscientific nature of our approach to the interpretation of physics. Wetter juxtaposes positivism to realism, includes dialectical materialism within realism, and then uses the critical-realist argument about the open questions in the natural sciences. This "subtle" change of front turns dialectical materialism into realism and emphasizes its opposition to positivism. But in regard to questions unanswered by the natural sciences, dialectical materialism has nothing to say, and neo-Thomism, everything. Here we find one of the main arguments against materialism: The unity of the world in its materiality is not established. However, Wetter recognizes, as we have seen, that microparticles exist independently of the process of observation. So, again, here arises the question about the character of this existence. In order to justify the idealist view that this existence has an ideal character, Wetter would have to prove the dependence of objective reality on an absolute mind, i.e., a consciousness independent of all material existence. Dialectical materialism bases itself only on those scientific results which uncover the objective laws of objectively real processes. This assumes that these processes have material causes, even if science has not discovered the specific cause for a given case. The assumption of ideal causes is incompatible with science and, as we showed when dealing with neo-Thomism, it is an unproved hypothesis which is based merely on the claim that our world is incomplete and finite.

Once again, we have confirmed what we already emphasized: the neo-Thomists pass silently over the problems involved in their own hypotheses and postulates. They consider all other philosophical directions as unproved and use their own views as the only possible yardstick for the interpretation of the natural sciences.

Wetter wishes to deal a fundamental blow to materialism by declaring it unproved. For this purpose he must obscure the basic question of philosophy and proclaim secondary differences between two idealist currents (positivism and critical realism) to be the main differences. This is meant to win over the natural scientists whose spontaneous materialism recognizes the existence of a real external world. By declaring Marxist-Leninist philosophy to be a realistic current with unproved assumptions, Wetter wants to prevent the natural scientist from passing from spontaneous to conscious materialism. However, dialectical materialism differs fundamentally from positivism, as well as from neo-Thomism and critical realism, because it generalizes the scientific results of thinking and the basic assumptions of scientific work and defends them against attack from all idealist directions.

Critical realism had, of course, some positive aspects. In the philosophical polemics at the beginning of the twentieth century it supported materialism and correctly dealt with methodological

problems of scientific research. For example, Bavink, in his book, *Results and Problems of the Natural Sciences — An Introduction to Current Natural Philosophy*,[30] particularly in the first part, had important things to say against positivism. In his *Philosophical Assumptions for the Exact Natural Sciences*, E. Becher argued against the positivist concept of hypothesis, in particular, Mach's.[31] Becher made convincing arguments against the view that there exists a hypothesis-free physics and showed the importance of the hypothesis for scientific work. It should not be forgotten that Becher's activities occurred during a period that brought to light many epistemological difficulties in natural science and a crtique of positivism was badly needed at that time.

And even if these polemics cannot be compared with those made by Lenin against positivism, it should be said that Lenin commented positively on Becher's criticism of Mach.[32]

The fact that critical realists or individual representatives of this school have made positive contributions in no way changes our fundamental assessment of them. Through their natural philosophy, positivism and critical realism try to give idealist interpretations of the results of natural science. Although their representatives believe that they stand above the materialist and idealist currents, our analysis has shown that positivism tends toward subjective idealism and critical realism toward objective idealism. The latter becomes particularly clear when critical realism and neo-Thomism join together.[33]

NOTES

Quotations in the text from sources designated with an asterisk (*) are from works that were originally in a language other than German and have been translated into English from the German edition of the present book.

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