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SCIENCE AND NATURE

The journal of Marxist philosophy for natural scientists

The masthead emblem represents the dialectical interpenetration of science and nature, suggesting the manifold interconnections between scientific knowledge, ideal in form, and the material nature reflected in this knowledge.

OUR REASON FOR BEING

Science and Nature is devoted exclusively to the philosophical problems of the physical, biological and formal (mathematical and logical) sciences. The editorial purpose is to demonstrate the usefulness of the Marxist world view in the practice of science, and thus bring philosopher and natural scientist to a closer and more effective working alliance in the scientific process. Subject matter includes applications of dialectical materialism and the Marxist theory of knowledge to research problems, as well as Marxist historical and sociological studies of scientific development and interaction with society as a whole. Complexity of treatment may range from the elementary tutorial to the highest professional level of creative additions to the body of Marxist philosophical knowledge.

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LETTERS TO THE EDITOR

On the Ecology of Ideas

The second issue is excellent. I was particularly impressed with Ozonoff's suggestion that one can think of an idea as a living organism struggling to survive in a hostile or beneficial ecological environment. Obviously, under capitalism a Konrad Lorenz has a better chance of spreading his beliefs than has a Marxist. Enclosed is my subscription renewal and a contribution.

Benjamin DeLeon, Cranston, Rhode Island

On Wave-Particle Duality

I continue to disagree with Lester Talkington on his basic approach to the problem of quantum electrodynamics (see "Contradiction in Wave-Particle Duality", *Science & Nature* No. 2). My basic quarrel is with his assumption that the photon can be treated in isolation, apart from the rest of quantum field theory. I believe that there are two fundamental problems with quantum field theory: the divergences that require infinite renormalizations, and the indeterminism which holds true of all quantum theory and lies at the root of wave-particle duality. The basic point is that both of these problems occur not only in QED, but in all quantum theory. A modification of QED which dealt with these difficulties would have to change the assumptions of all quantum theory, and not be based on a peculiarity of QED such as the masslessness of the photon. To say otherwise would be to claim that by coincidence, different mechanisms happened to lead to the same problems in QED as in the rest of quantum field theory. This is certainly possible but it seems extraordinarily unlikely. From what I have seen so far, my suspicion is that Talkington's approach does not challenge anything basic enough to really touch the problems of indeterminism in quantum theory and QED.

Steve Carlip, Somerville, Mass.

Concerning Dialectics Workshops

It seems to to me immensely valuable to have such meetings (Dialectics Workshop, Columbia University 1 Dec 1979). But it also seemed to me that throughout the day the notion of materialist dialectics was not developed sufficiently. It was almost as if dialectics means nothing else but qualitative change. I hope that we can work out more fully the various kinds of significance that make up this notion and have them serve us as useful guidelines on the implications for the various disciplines of learning.

A primary interest for me concerns the implications of current scientific developments for our understanding of man's place in nature.

To keep our bearings in this torrent of new knowledge we need the interpretation of scientists who have command of materialist dialectics. Another connection for me is the struggle with the kind of mentality that reflects the long history of positivist science. We constantly find among our students inheritors of that tradition who appear obtuse to the human significance—the poetic meaning, one might say—of the condition of man and woman in our time. There is a need for passionate involvement in these questions on the part of revolutionary intellectuals who are not themselves scientists (I am primarily a student of literature).

Issues of your journal get away from me. I enclose a check for another copy of No. 2 and let the remainder be a donation.

Gaylord Leroy, Temple University (emeritus)

We had an organizational meeting of the Bay Area Dialectics Workshop on 15 Jan 1980. The meeting was successful enough to begin a small study group. We have had two meetings since then. The first stressed methodology, reviewing the material on Feuerbach in *The German Ideology* concerning the opposition between the materialist and idealist philosophies. The second discussed a 1969 paper by member Lee Coe on "The Nature of Time" (Amer. Jour. of Physics 37:810 and 39:117). At our next meeting Lee Coe will lead a discussion based on his manuscript opposing the big bang hypothesis on the origin of the universe. Our discussions have stressed the necessity of viewing things in their context: science in its cultural context; the object of study in its environmental context. Subscribers and others in the Bay area are welcome to attend. Please call 415-654-1619 for details.

Glenn Borchardt,
6035 Ocean View Dr., Oakland, CA 94618

Music to Our Ears

Congratulations on the second issue. I have heard a lot of praise of its high quality.

James Lawler, Philosophy,
State University of New York at Buffalo

The issues so far have been truly provoking, filling a real need for this kind of dialectical analysis of science. Enclosed is $10 for subscription renewal and a contribution. Keep up the good work.

Issar Smith, Public Health Research Institute of the City of New York

I find the content of the first two issues stimulating, the range of subjects opening wider horizons for me, the quality of thought and writing quite high.

H. Gil Peach, Tuckahoe, New York

A masterful job. All of the articles are interesting, cogent, useful in the classroom and in argumentation with scientists steeped in "categories".

Sidney J. Gluck, New School for Social Research

Congratulations on a lively and interesting journal.

Martin Zwick, Systems Science, Portland (Ore) State Univ.

An Abstract of Issue No. 1

(from *Journal of College Science Teaching,* March 1979)

SCIENCE AND MARXISM

First issue of *Science and Nature,* Fall 1978. Subscriptions at $10 per year are available from 130 St. Edwards St., Brooklyn, NY 11201.

Abstracted by Robert E. Filner

The appearance of this new journal, *Science and Nature,* comes at a time of growing interest on the part of historians and sociologists of science, as well as scientists themselves, in the relationship between science and ideology. And while most American scholars will not accept the political and philosophical assumptions of the journal, its lively and stimulating articles and its style are a welcome additional to the literature.

Science and Nature is subtitled "the journal of Marxist philosophy for natural scientists." But it is not at all dogmatic in its efforts to explore the relevance of Marxist philosophy for understanding and guiding the scientific process. For example, Robert S. Cohen (Professor of Physics and Philosophy at Boston University), in his "Karl Marx on Science and Nature," doubts that dialectical relations are an inherent part of nature; the editor, in a rejoinder, disagrees. In "Barry Commoner and the Second Law of Thermodynamics," David L. Morgan (University of Northern Iowa) criticizes Commoner's brand of Marxism as expressed in *The Poverty of Power.* And in an extremely interesting contribution, "On Intuition Versus Dialectical Logic," Nikilai N. Semenov (Nobel Laureate and Member of the Presidium, USSR Academy of Sciences) analyzes his own thought processes in discovering limiting phenomena in chemical kinetics

A nice feature of the journal is the printed discussion and debate that follows the contributed papers. In addition, it carries various notes, news items, book reviews, and bibliographic references.

Dimensional Analysis of the Hereafter

I remember [J. B. S. Haldane] at a dinner of the Society for Experimental Biology. It was a light-hearted informal occasion and for some reason J.B.S. was asked to make a speech. In that grave, hesitating voice, as though about to begin a scientific lecture, he said that although he could not bring himself to believe in heaven, he now had some inkling of what heaven would be like if there were such a place. For he had greatly enjoyed this dinner, "thanks to the delectable company of the young lady on my right and the young lady on my left. Now in a three dimensional world one can have only two ladies sitting next to one. Heaven, I believe, might be conceived to be a place in n-dimensional space, where one could therefore expect at dinner to enjoy the company of n-1 young ladies."

-- Eric Ashby, Conversations with Haldane, *Nature* 266: 782, 1977.

WHAT IS THE ESSENCE OF *Causality?*

IS IT *Statistical?*

CAUSALITY AND LAW*

H. Hörz, Hans-Dieter Pöltz, Heinrich Parthey,
Ulrich Röseberg, and Karl-Friedrich Wessel
G.D.R. Academy of Sciences and
Erfurt Higher Pedagogical School

I. 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 representatives of other scientific disciplines.

The structure of the laws of Newtonian mechanics are 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 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 there exists only one possibility which is necessarily realized

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*Abridged by Erwin Marquit, with concurrence of authors, from *Philosophical Problems in Physical Science*, Marxist Educational Press, 1980, Paper $8.50, Cloth $15.95; 75 cents postage (c/o Anthropology Dept., 215 Ford Hall, University of Minnesota, 224 Church Street, S.E., Minneapolis, Minn. 55455). Revised and translated from Berlin (G.D.R.) edition of 1978.

Initiating a discussion series on the interpretation of quantum mechanics. Which side are you on?

OR IS IT *Dynamical?*

CAUSALITY AND LAW: A CRITICAL COMMENTARY

Lester Talkington
Tappan, New York

Introduction

The philosophical interpretation of quantum mechanics has been a major source of mystification and obscurantism in our century. Even today it is seized upon by the idealists and god-builders (to use Lenin's term) to proclaim the end of causality, the "free will" of electrons, the new opening for a supreme being, and assorted subjectivist schemes by which the observer's consciousness can influence physical processes. This is the context in which we must evaluate the particular interpretation of causality proposed by Hörz et al. [accompanying article, this issue].

In effect, Hörz et al, offer us a new philosophical category of *statistical causality* and, moreover, propose it as the generalized category for the causality principle itself, thus relegating dynamic causality to a subordinate role not only in physics but in all reality. This topsy-turvy concept of causality must be examined rigorously since it implies, for example, that even the dynamics of economic forces should take a backseat to statistical laws. Considering that statistical analysis is notorious for its inability to distinguish between cause and effect, we must ask whether the concept of statistical causality represents any substantial advance over the Heisenberg claim of non-causality in microphysics. The question is all the more serious since the proposed redefinition of the causality principle is presented with the influential support of physicist Vladimir A. Fock.

I will argue that Hörz et al, present an inverted interpretation of causality, metaphysical in character, that constutures a conceptual barrier to the further advance of microphysics. My argument will be based on the

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in accordance with a certain law. 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 are 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.

Thus the whole world–nature and society–was seen as a gigantic system which exclusively obeyed the laws of mechanics.

The 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 therefore had far-reaching philosophical and ideological consequences. It inhibited 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 observe the dialectics of nature, that is, the 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 the 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 characterized it as "keeping idealism 'above', in the field of the science of society".

II. 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 purposeful activity of human beings. Causality provides a basis for the material unity of the world. It is part of the universal interconnection 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 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"[1]. And elsewhere, when examining the relation between interaction and causality, he states that closer investigation shows that cause and effect "are conceptions which only have validity in their application to a particular case as such, but when we consider the particular case in its general connection with the world as a whole, they merge and dissolve in the conception of universal action and interaction, in which causes and effects are constantly changing places, and what is now or here an effect becomes there or then a cause, and vice versa"[2].

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" [3].

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 objective 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 of *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 nonessential relations. This demands acceptance of differing relations in 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 that everything in the world is cause and effect, that there are no material changes which arise without a cause and which do not produce effects.

If, beside 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 definition 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 *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 universally necessary and essential connection among things, processes, and systems of objective reality, which are marked by relative constancy of conditions and reproducibility.

III. 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 *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 local action. This leads 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 in particular 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 local action, 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 vacuo) 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 the space-time character of events that could be causally related.

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 simplifications 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 relations 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 the position and momentum of a physical object at the same time with arbitrary accuracy. But this is precisely the assumption for the conception of causality and law in macromechanics as described above in subsection I.

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 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 definitely shows the invalidity of the causal law" [4].

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

- that Heisenberg, like the majority of physicists at the time, understood "causal law" to be the classical-mechanical form of causality;
- that the probability-theoretic features of quantum mechanics corresponds to microphysical processes and phenomena and therefore cannot be explained in terms of insufficiency of knowledge, but are of objective character;
- that Heisenberg, by concluding that the "causal law" is invalid because one particular form of it typical for a given causal connection does apply to another domain, unjustifiably bases a sweeping philosophical conclusion on physical knowledge.

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 this problem for many years. The dispute was primarily 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 mechanism. 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, "the necessity of considering the concept of probability as an essential element of description, and not as a sign of incompleteness of our knowledge, results from the fact that under given external conditions, the result of the interaction between the object and the measuring instruments is not, in general, clearly determined, but has only a certain probability. A series of such interactions leads to statistics to which there correspond a certain probability distribution. The probability distribution reflects the objectively existing potential possibilities under the given conditions" [5].

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 whole 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, eliminatable. We note, however, that the theoretical basis of the statistical laws also continues to be discussed [6].

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" [7].

The statistical character of the laws of quantum physics, therefore, is 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 generally necessary, that is, reproducible and essential, connection among things, processes, etc. in the objective reality which determines the character of the phenomenon,* whereby

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

It links the necessary realization of the system possibility with the chance realization of the element possibilities, the former 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 without their connection to, that is, in isolation from, other events.

Thus the element possibilities are realized by chance, but with a definite probability. Mechanical materialism 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. Stochastic distributions are not quite the same as statistical laws. The latter demand knowledge of those system possibilities which assert 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 that actually decays 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 of 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 are more strongly emphasized through the *motion-possibility-probability* relations in the quantum-mechanical form of causality.

We will close with a comparison of law and causality. In a way, the concept of law goes further than the concept of causal relations. The category law represents a wide range of different forms of generally 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.

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 process 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 generally necessary and essential relations existing 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 nonessentialness, while law embraces the essential, generally 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 begin 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 law may contain a time dependence. □

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Continued from page 5

dialectics of the cognitive process that necessarily develops step-wise, from one qualitative level of knowledge to another deeper level, whereas Hörz et al, base their entire proposal on the relatively superficial level of microphysical understanding embodied in the statistical character of quantum mechanics. In this argument, I will develop materialist views with respect to three philosophical concepts—dynamics, predictability, and completeness—that figure prominently in their interpretation of quantum mechanics.

Some preliminary comments

Quantum mechanics is a mathematical formalism that was developed in good part out of efforts to understand atomic structure through the manifestations of atomic spectra. The statistical character of the formalism therefore reflects the probabilistic nature of photon distributions in the spectra studied. Considering this origin, it is not surprising that the formalism as yet yields exact quantitative results only for interactions of photons and electrons (quantum electrodynamics); yet even here, it is plagued by anomalous infinite energies that are resolved only by *ad hoc* techniques of renormalization. In its application to nuclear and high-energy interactions (quantum field theory), only qualitatively correct results have been achieved to date while the mathematical difficulties and the physical paradoxes (e.g., virtual particles) have become more exaggerated.

The formalism has been developed in a logically complete form, in the sense that it can be axiomatized and used to solve practical problems. The Heisenberg uncertainty relation is an integral part of this formal system. The dynamics of particle interactions are reflected in the formalism by the use of classical dynamic variables to formulate the wave function ψ and by the role of operators in effecting changes of state; but this reflection of reality is so partial and indirect that the formalism yields no physical picture for the mechanisms of the interaction process itself.

In the original Bohr-Heisenberg (Copenhagen) interpretation, the uncertainty relation and the lack of a physical picture provided the logical basis for denying that causality applied in quantum processes. According to historian Loren Graham [1971 pp 93-101], Fock was an early (1930s) supporter of the original Copenhagen interpretation: "Most of Fock's effort in interpreting quantum mechanics has been toward establishing the fact that the Copenhagen interpretation... did not violate dialectical materialism." In the early 1950s Fock came under heavy criticism in the USSR for idealism in certain aspects of his support to Bohr. After a meeting with Bohr in 1957, both scientists began to change their positions somewhat. That Fock's new position was essentially the view presented by Hörz et al. can be seen from the Graham [1971] report:

> Our new approach, said Fock [in 1959], should be to understand causality as an affirmation of the existence of laws of nature... Causal laws can, therefore, be either statistical or deterministic... Fock concluded his remarks on causality by commenting that in his recent conversations he had found Bohr in agreement with these observations. *Thus a few redefinitions of complementarity and causality would go far toward strengthening the Copenhagen interpretation* [emphasis added].

This bit of history poses for us two new questions: (1) Is not the concept of causality vulgarized by reducing it to the concept of lawfulness? (2) Does not the conciliatory nature of the comments by Hörz et al. concerning Heisenberg's championship of non-causality perhaps reflect an inherent affinity between the Bohr-Heisenberg and the Bohr-Fock interpretations? These questions give added significance to the original question concerning whether the concept of statistical causality differs materially from non-causality.

On the dynamics of causality

The contention that causality is primarily statistical rather than dynamic in nature is hardly a new idea. Jammer [1966 pp 166-80] traces its development from idealist sources in the nineteenth century. In essence, thic concept assumes that macroscopic determinism is actually a statistical effect and that individual microentities have an innate contingency in their behavior, supposedly governed by inexplicable chance much as if particle motion were determined by an internal random-number generator. This concept emerged anew in the interpretation of quantum-mechanical formalism that views the wave function ψ as a "probability wave" accompanying the individual particle and influencing its behavior.

The abstract nature of such interpretations is reflected in the logical empiricist form of the causality definition given by Hörz et al.:

> 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 ... In the quantum-mechanical form of causality we take probability... 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.

We can see that the above "definition" actually refers to a relation of states, rather than to underlying causal mechanisms, if we compare it to the ontological relationships described by G. A. Svechnikov [1971 p 64] as follows

> Causality expresses the mechanism which generates a phenomenon or a change in a thing... The relation of states only reflects the fact of a change in a thing, its transition from one state to another.
>
> The cause is of a dynamical (force) character and is expressed in an action or an interaction of bodies.
>
> The state of a body, on the other hand, at a given time affects the state of the body at a subsequent time, but the influence is not

of a dynamical (force) nature...

> Cognition of the cause refers to the question of the source of motion and change in a thing, stating why phenomenon occurred. Cognition of a relation of states only describes the result of the motion. Causality explains the phenomenon, the relation of states describes the course of its variation in time.

Svechnikov [p 11] also notes how, in the scientific literature and in colloquial speech, the dynamic character of the cause is frequently denoted by means of such words as "motive force", "impulse", "source of motion", etc. Certainly, when Engel [1940] originated the concept of reciprocal action or *interaction* as a generalization of the force concept, he repeatedly discussed causality in terms of dynamic processes, as in his conclusion: "Only from this universal reciprocal action do we arrive at the real causal relation" [p 174]. The present usage of the term interaction to include discontinuous changes in motion and creation/annihilation processes (changes of state not yet explained in terms of causal mechanisms) in no way negates the necessity that the unknown microphysical processes are of dynamic character.

The inherently dynamic character of causal processes is found to be equally true, for probabilistic phenomena. For example, in classical physics, even the most profound statistical principles, such as the thermodynamic laws, are taken as macroscopic effects to be explained in terms of statistical mechanics, that is, by theoretical models relating observed averages to the force laws which operate at the level of microscopic events.

But Hörz et al. assert just the opposite: that this interpretation of statistical law is only a one-sided and mechanistic view even for macrophysics. How do they arrive at such an interpretation? First of all, they deny a primary causal role to dynamic law, restricting its applicability to an "aspect" of the overall system, i.e., macrophysics, while the behavior of system elements (microparticles) is specified as having a "stochastic aspect" (innate randomness). Thus they transform dynamic law into a mere "aspect" of causality, while attributing to statistical law the primary role in causality as a "generally *necessary*, that is, reproducible and *essential*, connection among things, processes, etc., in the objective reality that *determines* the character of the phenomenon" [emphasis added].

In such a topsy-turvy interpretation, turning the cognitive levels upside down, the determining influence must reside at the level of the empirically-observed probabilistic phenomena while the existence of dynamic causal mechanisms to be comprehended theoretically is a possibility not even considered. Also ignored are the dynamic underpinnings of the Schroedinger equation, that is, the dynamic variables of the wave function and the dynamic role of the operators. This approach follows the tradition of the Copenhagen interpretation in seeking to conceal the underlying dynamics of quantum-mechanical formulations. Niels Bohr characterized quantum mechanics as "a formalism... in which *the*

kinematical and dynamical variables of classical mechanics are replaced by symbols subjected to a non-commutative algebra... *a purely symbolic scheme* permitting only predictions, on lines of the correspondence principle" [Schilpp 1951 pp 207, 210, emphasis added]. In this tradition, Bohr [ibid. p 211] said that "the viewpoint of complementarity may be considered as a rational generalization of the very ideal of causality". Today Hörz et al., in the same spirit, say that the "dialectics of nature is more strongly emphasized" in the quantum-mechanical form of causality expressed as probability. The reader may judge which statement makes least sense.

On predictability versus uncertainty

Another important question raised by the interpretation of Hörz et al. concerns the relation of predictability to causality. In seeking to justify the concept of statistical causality, they consider only the alternatives of an indeterminism from the Heisenberg uncertainty relation and a Laplacian type of mechanistic materialism, the latter characterized by absolute precision of knowledge and absolute accuracy of prediction, by extrapolation of laws beyond the realm of their applicability, and so forth. This line of argument closely parallels that of Heisenberg except that statistical causality has been replaced by non-causality.

Since today there seem to be few if any serious proponents of such a Laplacian mechanistic determinism, this seems a rather superficial argument. Anyway, the basic Marxist criticism of the Laplacian concept of an absolutely predictable universe concerns its assumption of absolute knowledge concerning both laws and events. Marxism does not challenge the assumption that causal mechanisms determine the outcome of individual events. Quite the contrary: Marxism, like all science, assumes that any causal law is deterministic in the realm to which it applies. One of the major problems in all scientific effort, however, is to determine the limits of that realm; we can know such limits only to the extent that the law can be studied in isolation from the world of chance events and unperceived influences. And knowledge gained of causal mechanisms still cannot give unlimited predictive power because of the same difficulty in controlling for the effect of unknown and chance influences. In this context, causally determined events and chance events represent a dialectical unity of opposites at a given level of cognition; at some other level, the chance event must be causally determined.

This seems the correct formulation for the dialectics of necessity and chance in the scientific cognition process, identifying dynamic law with causal necessity for the phenomenon under investigation. In the particular case of chance events occurring with a regularity that provides the basis for statistical law, the governing causal mechanisms are to be sought not in the probability distribution itself but rather in the dynamic influences that determine the probability distribution. Such dynamic influences may be not at all clear from the observed phenomena, but the purpose of science is precisely to learn the underlying causal laws (Newtonian, Maxwellian, nuclear, or whatever), rather than to ascribe causality to their effects. In this view, the quantum-mechanical formalism provides a description of effects rather than causes. Hence, the Heisenberg indeterminacy relation itself should be interpreted as an effect rather than elevated to the status of a metaphysical principle given precedence even over the causality principle.

David Bohm [1952] pointed to the essential role of cognitive levels in dealing with this question:

> The uncertainty principle is obtained as a practical limitation on the possible precision of measurements. This limitation is not, however, inherent in the conceptual structure of our interpretation.

It remains to be seen what form indeterminacy will assume in microphysics when the underlying causal mechanisms are known. The same reservation applies concerning an eventual *physical* explanation of complementarity (wave-particle duality), which comes in the same package as indeterminacy so far as philosophical interpretation is concerned.

The question of completeness

A third basic point of controversy in the interpretation of quantum mechanics concerns whether the formalism is "complete". On this point it is necessary to ask "Complete with respect to what?" Who would argue that it is not complete in the logical sense described above (*Some preliminary comments*). And who would deny that the formalism is in some sense incomplete since it is unable to describe particle trajectories or the *process* of a particle interaction. In taking the position of Fock that the quantum-mechanical description of atomic processes is complete and refers to the individual objects, Hörz et al. never clearly define their criteria of completeness. Implicit in their interpretation, however, is the same metaphysical finality that was expressed openly by Gerald Feinberg [1977 p 86] that most physicists "remain convinced that randomness in the occurrence of individual atomic or subatomic events is a fundamental feature of the world, rather than an artifact of human ignorance. None of the developments in the fifty years since quantum mechanics was invented has given reason to think otherwise."

Nevertheless, there are some scientists who continue to "think otherwise". Albert Einstein maintained all his life that quantum mechanics failed to provide a complete physical description of the individual object or system in real situations and predicted that theoretical physics in the future would treat statistical quantum theory as the analogue of statistical mechanics [Schilpp 1951 pp 666-72]. And P.A.M. Dirac [1978 p 10 takes the same position today:

> I think it might turn out that ultimately Einstein will prove to be right, because the present form of quantum mechanics should not be considered as the final form... I think that it is quite likely that at some future time we may get an improved quantum mechanics in which there will be a return to determinism and which will therefore justify the Einstein point of view. *But such a return to determinism could only be made at the expense of giving up some other basic idea which we now assume without question.* We would have to pay for it in some way which we cannot yet guess, if we are to reintroduce determinism. [Emphasis added.]

Dirac certainly seems correct in pointing out that some false concept is preventing further development of microphysics today, that some ideological barrier is diverting us from the development of a more complete, more *physical* theory.

Note that neither Dirac nor Einstein have proposed an alternative model to meet this need. Other physicists such as David Bohm [1957] and Shoichi Sakata [1978], who also criticized quantum mechanics from the standpoint of completeness, have failed to propose useful alternative models. Many able scientists have tackled the same problem without useful results. And quantum mechanics is so fully developed by now that the answer can hardly depend on more experimental data. So what exactly is the nature of the conceptual difficulty that keeps physicists from breaking through to a more complete physical description of atomic processes? This type of question obviously cannot be addressed fruitfully without the proper philosophical tools at hand. I wish to demonstrate that here again the concept of cognitive levels proves indispensable.

My demonstration starts from what is probably the most non-controversial statement that is possible in the interpretation of quantum mechanics, namely, that the microentity and its macroenvironment must be treated as a single system. Hörz et al. attribute to Fock a very clear operational description of the statistical aspects of this matter:

> ...under given external conditions, the result of the interaction between the object and the measuring instrument is not, in general, clearly predetermined, but has only a certain probability. A series of such interactions leads to statistics to which there correspond a certain probability distribution.

Though few would disagree with this simple statement, it is nevertheless subject to widely divergent interpretations. In the Bohr-Fock view, this statement is taken to prove the somewhat trivial point that probability appears "as an essential element of description and not as a sign of incompleteness of our knowledge"; thus they dispel the subjectivist argument that characterizes the fortuitous as that for which the cause is unknown (while they defend the *stochastic* elsewhere in their interpretation). In classical physics, on the other hand, such a description of statistical results would be normally interpreted as an open invitation to investigate theoretically the underlying dynamics of interaction between the object and the measuring instrument in order to determine the cause of the observed variation in the result from one object to the next, especially since this variation has an observed regularity that can be described by statistical law. The stumbling block for this interpretation, however, is that the quantum-mechanical formalism provides no methodology for dealing more explicitly with environmental macrostructures such as measuring instruments. What does philosophy have to offer in this situation?

On the usefulness of philosophy

The only discussion I have found dealing directly with this problem is that of Svechnikov [1971 pp 167-72] who develops an explicit model for investigating the causal dynamics of interaction between a particle and its macroworld. "At the present level of scientific development," he writes, "scientists studying microentities ignore the microstructure of the measuring device and regard it as a macroscopic body." Yet, he points out, the "admission of interaction between instrument and microparticle is actually an admission that the behavior of a microparticle is causally governed by its interaction with... all the objects of its environment, including all particles of the experimental setup." Svechnikov in effect suggests a research program in which the measuring instrument itself is to be treated as a structure of microentities for theoretical and experimental investigation of their interaction with the particular microentity under study. Chiding those who see "insurmountable difficulties" in the task of breaking down the interacting system into its components, he reminds them that the task of science is to determine new inner properties of particles from changes that occur in the process of interaction, just as has been done already in revealing such properties as rest mass, charge, and spin.

Svechnikov's philosophical insight illuminates the whole question of "completeness" in science, showing that the question cannot be addressed meaningfully except in terms of cognitive levels. Logical completeness at, say, the quantum-mechanical level of description represents only a particular level of scientific development in the endless dialectical perspective of the relative and the absolute. Through the dialectical mode of thought and creative use of materialist principles, Svechnikov [1971 p 212] reached the same conclusion as Dirac, quoted earlier, on the conceptual nature of the roadblock faced in microphysics, but formulated here in terms of a concrete research program:

> The question of the possibility of constructing a dynamical theory of motion of an individual microentity within the framework of quantum mechanics remains open and its solution is apparently possible only if we give up some of the propositions of quantum theory.

Consider now the vast difference between the two approaches discussed here. On the one hand, we have the metaphysical (anti-dialectical) concept of statistical causality and quantum-mechanical completeness, the Bohr-Fock interpretation as presented by Hörz et al., that provides no pointer on the direction to a search for new understanding of microphysics and no motivation for undertaking any such search. On the other hand, we have the dialectical concept of cognitive levels, as developed by Svechnikov, with its stimulating challenge to search for the dynamical mechanisms of microphysical causality that are now hidden from view beneath the veil of idealist and metaphysical interpretations over a useful though imperfect quantum-mechanical formalism. The contrast of these two philosophical approaches provides an

adequate basis for judging which interpretation of completeness serves to extend and deepen our understanding of microphysics.

It seems appropriate to close with a Marxist comment from an unfinished note that seems just as relevant today as when it was written a century ago. Recall that the interpretation of Hörz et al. incorporated a "stochastic aspect" in their definition of statistical law, and thus introduced an element of the innately random or *inexplicable change* into the concept of statistical causality. Let us now see how Frederick Engels [1940 p 231 emphasis added] showed the dead-end to which such metaphysical reasoning leads:

> What can be brought under laws, hence what one *knows*, is interesting, what cannot be brought under laws, and therefore one does not know, is a matter of indifference and can be ignored. *Thereby all science comes to an end, for it has to investigate precisely that which we do* not *know...*
>
> Anyone can see that this is the same sort of science as that which proclaims natural what it can explain, and ascribes what it cannot explain to supernatural causes; whether I term the cause *inexplicable chance*, or whether I term it God, is a matter of complete indifference...

Today, whether we explain the observed phenomena in terms of statistical causality [unexplained chance] or in terms of [super-natural] noncausality is a matter of complete indifference; either interpretation tends to bring science to a dead stop. □

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Illuminated by dialectical and historical materialism

MATHEMATICS:

Its Essential Nature and Objective Laws of Development

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Photo, O. Kusmin
Tass from Sovfoto

Translation editing by Esther R. Phillips from translations by Gary Laison and by Michael Meo with Charles Aronson [from the 1956 Russian edition].

Editorial note: We present two philosophical essays that were omitted from the 1963 translation—by the American Mathematical Society—of the much-respected Soviet exposition, *Mathematics: Its Content, Methods and Meaning,* edited by A.D. Aleksandrov, A.N. Kolmogorov, and M.A. Lavrent'ev. These essays were the concluding sections of Chapter I, "A General View of Mathematics," written by Aleksandrov with assistance from V.A. Zalgaller. For those who have not read the chapter, we preface the essays with a summary of the portion previously published in English. A comment on the censorship aspect is appended.

Summary of Sections 1 through 7, prepared by Irving Adler

Aleksandrov begins by listing some characteristic features of mathematics: "its abstractness, its precision, its logical rigor, the indisputable character of its conclusions, and finally, the exceptionally broad range of its applications." In a preliminary clarification of these characteristic features, with emphasis on specific examples from the history of arithmetic, algebra and analysis, some of the points he makes are:

- All the abstract concepts of mathematics are "connected with actual life both in their origin and in their applications."

- Theorems in mathematics must be proved by logical argument from axioms.
- "The rigor of mathematics is not absolute. It is in a process of continual development."
- "Mathematical concepts. . . are brought into being by a series of successive abstractions and generalizations, each resting on a combination of experience with preceding abstract concepts."
- ". . . The development of mathematics is a process of conflict among the many contrasting elements: the concrete and the abstract, the particular and the general, the formal and the material, the finite and the infinite, the discrete and the continuous, and so forth."
- "The old theories, by giving rise to new and profound problems, outgrow themselves, as it were, and demand for further progress new forms and new ideas."

As a result, the growth of mathematics has led to a succession of qualitative changes. Aleksandrov discerns four distinct stages in the development of methematics:

1. The period of the formation of arithmetic and geometry as collections of rules deduced from experience and immediately connected with practical life.
2. The period of elementary mathematics, dealing with constant magnitudes.
3. The period of the birth and development of analysis, the mathematics of motion and change, which embraces the study of variable magnitudes.
4. The period of contemporary mathematics, characterized by an immense extension of the subject matter of mathematics and its applications; the formation of general concepts on a new and higher level of abstraction; the dominance of the set-theoretic point of view; and the interpenetration of all of the various branches of mathematics. *"Contemporary mathematics is the mathematics of all possible (in general, variable) quantitative relations and interdependences among magnitudes."*

His summary and conclusions are then given in Sections 8 and 9, which follow:

SECTION 8

The Essential Nature of Mathematics

1. Based on what has been discussed already, we may now turn to some general conclusions concerning the nature of mathematics.

The nature of mathematics was described by Engels in a section of *Anti-Duhring,* and we quote this remarkable passage here. The reader will easily recognize in Engels' formulation what we have already said, for example, with regard to arithmetic and geometry—and understandably so— since we explained the actual history of the origin and development of mathematics, guided by an understanding of dialectical materialism. Dialectical materialism leads to true results precisely because it does not superficially impose anything on reality, but examines the facts as they are, i.e., in their necessary relationships and development.

Engels begins his discussion of the nature of mathematics with some critical remarks about the absurd opinions of Duhring, in particular the false opinion that mathematics is engaged in the creation of "pure reason", independent of experience. Engels wrote:

> But it is not at all true that in pure mathematics the mind deals only with its own creations and imaginations. The concepts of number and form have not been derived from any source other than the world of reality. The ten fingers on which men learnt to count, that is, to carry out the first arithmetical operation, may be anything else, but they are certainly not a free creation of the mind. Counting requires not only objects that can be counted, but also the ability to exclude all properties of the objects considered other than their number—and this ability is the product of a long historical evolution based on experience. Like the idea of number, so the idea of form is derived exclusively from the external world, and does not arise in the mind as a product of pure thought. There must be things which have shape and whose shapes are compared before anyone can arrive at the idea of form. Pure mathematics deal with the space forms and quantity relations of the real world—that is, with material which is very real indeed. The fact that this material appears in an extremely abstract form can only superficially conceal its origin in the external world. But in order to make it possible to investigate these forms and relations in their pure state, it is necessary to abstract them entirely from their content, to put the content aside as irrelevant; hence we get the point without dimensions, lines without breadth and thickness, *a* and *b* and *x* and *y*, constants and variables; and only at the very end of all these do we reach for the first time the free creations and imaginations of the mind, that is to say, imaginary magnitudes. Even the apparent derivation of mathematical magnitudes from each other does not prove their *a priori* origin, but only their rational interconnection. Before it was possible to arrive at the idea of deducing the *form* of a cylinder from the rotation of a rectangle about one of its sides, a number of real rectangles and cylinders, in however imperfect a form, must have been examined. Like all other sciences, mathematics arose out of the *needs* of men; from the measurement of land and of the content of vessels, from the computation of time and mechanics. But, as in every department of thought, at a certain stage of development the laws abstracted from the real world become divorced from the real world, and are set over against it as something independent, as laws coming from outside, to which the world has to conform. This took place in society and in the state, and in this way, and not otherwise, *pure* mathematics is subsequently *applied* to the world, although it is borrowed from this same world and only represents one section of its forms of interconnection—and it is only just precisely because of this that it can be applied at all. [*Anti-Duhring*, New York 1939, pp. 45-46.]

2. Thus, Engels emphasizes that mathematics reflects reality, that it arose from practical needs of people, and that its first concepts and principles came as a result of a long historical development grounded in experience. We have already examined this in abundant detail in the examples of arithmetic and geometry. We have convinced ourselves, in particular, that the ideas of number or magnitude and of geometrical figures arose in this way, and that they reflect the real quantitative relations and spatial forms of reality. The fundamental ideas of analysis reflect real quantitative relations in exactly the same way. They are built up gradually, beginning with generalizations of enormous amounts of concrete material; thus, the concept of function is a reflection, in generalized abstract form, of various relations between real quantities.

Summarizing all this, Engels arrives at the fundamental conclusion: *mathematics has real matter as its subject, but considers it in complete abstraction from its concrete contents and qualitative peculiarities.* In this respect it is clear that mathematics must be distinguished from the natural sciences, and Engels clearly makes this distinction [*Anti-Duhring*, pp 45-47].

The possibility of abstractly examining the subject of mathematics is objectively based in the subject itself. Its general forms, relations, interconnections and laws—independent of the specific peculiarities or concrete content— exist objectively, independent of our knowledge of them. Thus, the existence of number as an objective property of sets of objects, the independence of numerical relationships from the specific properties of the objects, and the richness of these relationships, made arithmetic possible. Where such common forms and relations, independent of content, do *not* exist, there mathematical examination is impossible.

3. The aforementioned fundamental characteristic of mathematics determines other characteristic properties. In Section 2 we examined some of these special features in the case of arithmetic. These are: the specific "formal language", the wideness of application, the abstraction of results from experience, their logical inevitability, and their persuasiveness. The theoretical character of mathematics is clearly an essential feature of it, and we now examine this feature in detail.

If we abstract, for example, the idea of number from its concrete base and consider pure numbers in general, apart from any relation to one or another concrete collection of objects, then it goes without saying that we are not able to carry out experiments on such abstract numbers. Remaining at this level of abstraction without returning to the concrete object, it is possible to get results about numbers only by means of arguments based on the *concept* of number itself. The same applies, of course, to all other mathematical results. Remaining within the limits of pure geometry, i.e., considering geometrical figures completely abstracted from any qualitative, concrete content, we can derive new results only by reasoning from the very *concept* of this or that figure, from the basic concepts of geometry or from the axioms themselves. Thus, properties of a circle are deduced from the idea of a circle as the geometric locus of points equidistant from a given point, and by no means is each theorem verified by experience.

Therefore, *the abstract character of mathematics is already predetermined by the fact that mathematical theorems are proved only by reasoning, based on the concepts themselves.*

It is possible to say that in mathematics we investigate quantitative relations, keeping in mind only what is contained in the definitions themselves. Correspondingly, mathematical results are obtained by arguments derived from the definitions. Of course, it would be incorrect to interpret this too literally and to suppose that sufficiently rigorous definitions of mathematical ideas were actually formulated before the creation of the corresponding mathematical theories; indeed, the concepts themselves were made more accurate in the course of the development of the theory and as a result of this development. A profound analysis of the idea of whole number, as well as a precise formulation of the axioms of geometry was not carried out in antiquity but at the end of the 19th century. It would be even more wrong to think that there is some kind of class of absolutely, precisely determined mathematical ideas. Every concept, however precisely defined it may seem, is nevertheless mutable—it evolves and is made more precise with the development of the science. This is completely demonstrated by the development of mathematics in relation to all its concepts, and it only confirms once again the fundamental proposition of dialectics that there is nothing in the world which is immutable and not subject to development. Thus, with respect to mathematical ideas, we may speak, in the first place, only of sufficient, but not of absolute, precision, and, in the second place, we must keep in mind that the precision and clarity of its definitions and the depth of its analysis evolved with the development of mathematics. On the subject of the changing character of mathematical concepts we shall have more to say in the following section; but now, keeping in mind the above remarks, we consider in detail the adequacy of the precision.

This precision of the mathematical concepts—along with the general applicability of logic itself—appears to be the reason for the inner persuasiveness and logical necessity which are characteristic of mathematical results. The inevitability of the theoretical results of mathematics gives rise to the erroneous idea that mathematics has its foundation in pure thought, that it is *a priori* and not derived from experience, that it does not reflect reality. The famous German philosopher Kant, for example, arrived at this point of view. This deeply erroneous ideological notion arises, in particular, when mathematics is considered in its finished form and not in terms of its actual origins and development. But this approach is quite sterile, for the simple reason that it does not correspond to the actual state of things. For it is firmly established that mathematics is not *a priori*, but arose from experience. In fact, the

actual origins of geometry were written about by Eudemus of Rhodes, whom we quoted in Section 3.

Not only the concepts of mathematics, but also its results and its methods reflect reality. This important point is stated clearly by Engels, who writes: "Even the apparent derivation of mathematical magnitudes from each other does not prove their *a priori* origin, but only their rational inter-connection." Mathematical results and proofs arose as reflections of real relations which people investigated in their experience. The addition of numbers reflects the actual combination of several objects aggregated into one. The well-known proofs of theorems about equality of triangles, in which one speaks of their superposition, certainly have their origin in the operation of actually applying one object to another; this constantly takes place in the comparison of their sizes. The calculation of volumes by integration reflects in abstract form the real possibility of building up bodies from fine layers, or of slicing them into such layers. More complicated mathematical proofs are results of a further development originating from this material foundation.

4. The complete abstraction of the objects of mathematics from everything concrete, and the theoretical character of the mathematical results which are based on it, have as a consequence another important feature of mathematics: in mathematics we investigate not only quantitative relations and spatial forms which are immediately abstracted from reality but also relations and forms which are defined within mathematics on the basis of concepts and theories which have already been put together. It is just this feature of mathematics which Engels considers when, referring to the origin of the concepts of points, lines, constant and variable quantities, he says: "Only at the very end of all these do we reach for the very first time the free creations and imaginations of the mind, that is to say, imaginary magnitudes."

The historical fact is that imaginary numbers were not taken from reality in the same sense as, say, integers. They appeared originally within mathematics itself, a product of the necessary development of algebra, as roots of equations of the form $x^2 = -a$ (where $a > 0$). Although, gradually, operations with them were carried out quite freely, their real meaning remained for a long time unclear, which is why they acquired the name "imaginary". Subsequently their geometric interpretation was discovered, and numerous important applications were found. In precisely the same way, Lobachevskian geometry originated as the creative product of the great scientist; he did not see its real significance and consequently named it "imaginary geometry". However, it was not free play of mind but the inevitable result of the fundamental concepts of geometry, and Lobachevsky considered it as a possible theory of spatial forms and relations. Thus, it is not possible to interpret "the free creations and imaginations" of which Engels speaks as simple arbitrariness of thought. Free creation in science: this is a realization of logical necessity, determined by the concepts and the initial positions taken from experience.

In the most recent stage of the development of mathematics, the beginning of which can be precisely placed at the time of the construction of Lobachevsky's geometry and the precise meaning of imaginary numbers, new concepts and theories appeared and continue to appear; these are based on previously constructed concepts and theories which need not borrow directly from reality. Mathematics defines and investigates the possible forms of reality; this is one of the decisive characteristics of the recent stage of its development.

A correct understanding of this characteristic is provided by the theory of knowledge of dialectical materialism. Lenin wrote: "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..." [*Philosophical Notebooks,* Moscow 1963 p. 182]. Metaphysical materialism also recognizes that knowledge, in particular mathematical knowledge, is a reflection of nature. However, as Lenin notes, the weakness of metaphysical materialism is its inability to apply dialectics to the theory of reflection [ibid, p. 362]. Metaphysical materialism does not understand the complexity of this reflection, does not understand that it goes through a series of abstractions by the formation of new concepts, by the construction of new theories on the basis of concepts and theories previously constructed, and by the examination not only of the data of experience but of its possibilities. This transition from data to possibilities is already manifested in the formation of such concepts as arbitrary whole number or infinite straight line, since there is no data in experience of either arbitrarily large integers or infinite extension. But when the concept of number is crystallized, the possibility of the infinite continuation of the number sequence is manifested from the concept itself and from the law of formation of successive numbers by the addition of a unit. In the same way, the extension of a line segment reveals the possibility of its infinite extension, expressed in Euclid's second postulate: "Every straight line can be extended infinitely". Tne subsequent process of abstraction led to the concepts of the entire sequence of natural numbers and *all* of the infinite straight lines. In the most recent stage of the development of mathematics the construction of theories has been qualitatively new, passing through a sequence of abstractions and formations of concepts. But, going back along the path of these abstractions, we see that mathematics is by no means separated from reality. What is new arises on the basis of the reflection of reality, as a result of the logic of the subject itself, and particularly by means of the return to reality in applications to problems of physics and technology. So it was with imaginary numbers. It is also true in relation to other mathematical theories, however abstract they may be. A characteristic example is provided by the theory of spaces of n-dimensions. Such spaces were invented as generalizations of Euclidean geometry in conjunction with the development of algebra and analysis,

under the influence of mechanics and physics. The combination of these ideas led Riemann to the construction of the general theory which, developed further by other mathematicians, found a series of important application and, in the end, provided a ready mathematical apparatus for Einstein's construction of the general theory of relativity (more precisely, the theory of gravitation). It is no accident that abstract geometric theories found such brilliant applications, nor was it a result of "preordained harmony of nature and reason"; rather, it was a result of the fact that these theories grew out of geometry, which was directly grounded in experience, and that they were related, by their creators, to problems of investigating real space. Riemann, in particular, clearly foresaw the connection of his theory with the theory of gravitation.

Thus, in the development of mathematics, there is the law of the motion of knowledge formulated by V. I. Lenin: "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.* From living perception to abstract thought, *and from this to practice*—such is the dialectical path of the cognition of *truth,* of the cognition of objective "reality". [ibid, p 171.]

From what has been said it is clear that the idealist view—that mathematical theories constitute merely conventional schemes chosen to describe the data of experience, or to "order the stream of sensations" on the basis of the "principle of economy of thought"—is completely false.

Engels notes (as quoted earlier) that the propositions of mathematics, abstracted from the real world as if they were opposed to it, are applied to its study as some ready-made schema. For example, we continually make use of computations in the form of finished (tabulated) numbers. This is even more true of the theories arising at higher stages of abstraction. In the example already discussed, Riemannian geometry served as a readily available mathematical schema for the theory of gravitation. But Engels explains that the possibility of such an application of mathematics to the investigation of the real world is based on the fact that mathematics was borrowed from this world, and only expresses a part of its inherent forms of relations—indeed, *only because of this* can it be applied at all. The fact that many theories are created within mathematics itself does not change any of this. The development of applications of formal theories to reality is absolutely not a matter of convention; this development occurs as a consequence of the logic of the subject itself. In any case, mathematical theories reflect reality—the only difference among them being that the reflection is more immediate in some cases, while in others it goes through a series of abstractions, conceptualizations, etc.

5. The most recent stage in the development of mathematics is characterized not only by higher levels of abstraction; it is further characterized by the essential widening of its subject matter, by going beyond the limits of the initial concepts of quantitative relations and spatial forms.

Figures in a space of several dimensions—or of infinite dimensions—are not, of course, spatial forms in the usual sense in which we understand them when we have in mind ordinary real space, rather than the abstract spaces of mathematics. Such spaces have real meaning and reflect in an abstract way definite forms of analogous reality; for this reason, in contrast to ordinary real space, we might call them "space-like". In speaking of space of several dimensions, or of figures in it, we attach new content to the concept of space, so that it is necessary to distinguish clearly between, on the one hand, the generalized, abstract concept of space in mathematics and, on the other, the concept of space in its original sense as the universal form of the existence of matter.

The emergence at the end of the last century of the new discipline of mathematical logic, since developed extensively, will serve as another example of the way the subject matter of mathematics has broken free of the limitation to spatial forms and quantitative relations, in the original meaning of these terms. The object of consideration in this discipline is the structure of mathematical proofs; that is, it studies which propositions may be derived from given premises by prescribed rules. It investigates this subject, as is characteristic of mathematics, in complete abstraction from the content, thus replacing propositions by formulas and rules of inference by the principles of operating with these formulas. Relations between premises and conclusions, axioms and theorems, of course, do not reduce to spatial forms or to quantitative relations in their usual sense of relations between numerical values.

As another example, we consider the theory of groups which may be understood as the study of symmetries in the most general sense. The change in the symmetries of a crystal, say, in sulfur passing from rhomboidal to prismatic form, is a fundamental qualitative change of the state of the substance. In this sense, group theory is the study of quantities or defined qualities of an object, changes in which are accompanied by fundamental changes in the object itself.

A consequence of the extension of the subject matter of mathematics is the substantial extension of our understanding of quantitative relations and spatial forms. What then are the characteristic general features of this expansion in the subject matter of mathematics?

If we answer this question not by enumerating but by attempting to elucidate the common features of these subjects in all their various forms, then the answer is found essentially in Engels. It suffices to draw attention to his treatment not only of the subject matter of mathematics but also of the way in which mathematics deals with its subject matter: the complete abstraction of form and relations from their content. This abstract character of mathematics at the same time provides us with a definition of its content.

The subject matter of mathematics consists of those forms and relations of reality which objectively have such a high degree of indifference towards content that they can be completely abstracted from this content and defined in a general way with such clarity and precision, preserving such a wealth of relations, that they provide a basis for the purely logical development of the theory. If we call these forms and relations quantitative in the general sense of the word, it is possible to say briefly that the subject of mathematics consists of quantitative relations and forms viewed purely abstractly.

Abstraction is by no means the privilege of mathematics alone. Other sciences, however, are primarily interested in the degree of conformity of their systems of abstraction to a clearly defined collection of data; one of their important problems is the task of investigating the limits of the applicability of the theoretical system to the collection of data and determining appropriate changes in the abstract system. Mathematics, on the contrary, while investigating general properties in full abstraction from specific data, examines these systems of abstraction themselves in their abstracted generality, outside the boundaries of their applicability to individual concrete phenomena. One can say that for mathematics the absoluteness of abstraction is characteristic.

It is just the indicated indifference to the content of the forms investigated in mathematics which defines the fundamental properties of mathematics: its theoretical character, the logical necessity and apparent immutability of its results, the origination from within of its new concepts and theories; just the indifference to content determines the special character of the applicability of mathematics. When we can translate a practical problem into the language of mathematics, we may, at the same time, "abstract ourselves" from the concrete second-stage characteristics of the problem, and, by making use of general formulae and theorems, obtain precise results. In this way the abstraction of mathematics constitutes its power; this abstraction is a practical necessity.

6. Returning now to Engels' opinions about mathematics we can see their depth and richness, and the possibility of developing them further. Not himself a mathematician, he was able to make such a profound analysis of this science not only because he was a thinker of genius, but mainly because he was able to use dialectical materialism, and was guided by it in his explanation of the essence of mathematics. It is therefore not strange that no one before Engels was able to give so profound and correct a solution to this problem. Great mathematicians were unable to resolve the problem in this manner.

It was exactly in this way that Lenin later gave an analysis of the problem of physics that surpassed anything done in this area.

This demonstrates yet again the knowledge and power provided by dialectical materialism; it demonstrates that it is not enough to possess knowledge of individual propositions; nor is it sufficient to be a creative scientific worker—it is also necessary to possess the correct general method, to master dialectical materialism. Without this the results of science either will seem a shapeless heap or will present themselves in a distorted way; instead of a true understanding of science there will be a false metaphysical idealist representation of it. So, for example, many mathematicians who do not possess dialectical materialism are either completely disoriented in the general questions concerning their science or treat them in a completely inaccurate way.*

At the time when Engels wrote *Anti-Duhring*, i.e., in 1876-1877, non-Euclidean geometry and the geometry of space of several dimensions were just gaining acceptance among mathematicians, the theory of groups had just been formulated, the theory of sets had just appeared, and mathematical logic had only just been born. It is therefore obvious that Engels could not have given a detailed discussion of the characteristic properties of the latest stage in the development of mathematics; nevertheless, we can find in his opinions hints for understanding them.

SECTION 9

The Laws of Development of Mathematics

In conclusion, we shall attempt to describe briefly the general laws of the development of mathematics.

1. Mathematics is not the creation of any one historical epoch or of any one people; it is the product of a series of epochs and the work of many generations. As we saw, its first ideas and propositions arose in earliest antiquity and had already been put into a coherent system more than two thousand years ago. Despite all the transformations of mathematics, its ideas and results are preserved in the transition from one epoch to another, as, for example, the laws of arithmetic or the Pythagorean theorem.

New theories contain the ones which precede them—extending, sharpening, completing, and generalizing them.

At the same time, it is clear from the brief outline of the history of mathematics presented above that its development is not simply an accumulation of new theories but includes essential qualitative changes. Correspondingly, the development of mathematics can be separated into a sequence of historical periods with the transitions between them marked by fundamental changes in the subject matter or the structure of this science.

* It is interesting to observe, for example, that the two eminent American geometers Veblen and Whitehead attempt to define what geometry is in their book *Foundations of Differential Geometry* and conclude that it is impossible to give such a definition except perhaps the following: "geometry is whatever geometers say it is".

Mathematics includes in its province all new areas of quantitative relations of reality. At the same time, the most important objects of mathematics were and remain the spatial forms and quantitative relations in the simple, most direct meanings of these terms, and mathematical comprehension of new connections and relations inevitably arise on the basis of and in connection with previously constructed systems of quantitative and spatial scientific representations.

Finally, the accumulation of results within mathematics itself necessarily leads to the ascent to new levels of abstraction and new generalizations of concepts and thereby to a deepening of the analysis of the original concepts.

As a great and powerful oak thickens old branches with new layers, puts out new branches, extends upwards, and deepens its roots downwards, so mathematics in its development adds new material to its already existing areas, forms new directions of inquiry, ascends to new heights of abstraction, and deepens its own foundations.

2. Mathematics has as its subject the real forms and relations of reality, but, as Engels said, in order to study these forms and relations in pure form it is necessary to isolate them completely from their content, to put the latter aside as irrelevant. However, forms and relations do not exist apart from content; mathematical forms and relations cannot be absolutely indifferent to content. Consequently mathematics, by its very nature, aspiring to accomplish that separation, attempts the impossible. *This is the fundamental contradiction at the heart of mathematics.* It is the specific manifestation in mathematics of the general contradictions in knowledge. The reflection in thought of any phenomenon, any aspect, any amount of reality coarsens and simplifies it, wrenching it away from its general connections in nature. When people, studying the properties of space, ascertained that it was Euclidean, it was an exceptionally important act of cognition, although it contained an error: the real properties of space were taken simply, schematically, in abstraction from matter. But without this there would simply have been no geometry, and on the basis of this abstraction (by internal deduction, as well as by the confrontation of the mathematical results with new data of another science) new geometrical theories were produced and strengthened.

The constant resolution and re-establishment of such contradictions at new levels of knowledge ever more closely approximating reality constitutes the essence of the development of knowledge. This concept of development, of course, ascribes a positive content to knowledge, an element of absolute truth in it. Knowledge advances in an ascending line, and it is not rendered worthless by an admixture of error.

The fundamental contradiction, which we have indicated, leads to others. We saw this in the example of the opposition of the discrete and the continuous. (In nature there is not an absolute separation between them, and their separation in mathematics inevitably made necessary the creation of entirely new ideas profoundly reflecting reality, while at the same time overcoming internal imperfections in existing mathematical theories.) Exactly in this way the contradictions between finite and infinite, abstract and concrete, form and content, etc. appear in mathematics as manifestations of its *fundamental contradiction* defined above. But the decisive factor in its manifestations is that, in abstracting from the concrete and linking up its abstract ideas, mathematics separates itself from experience and practice; but at the same time it proves to be a science (i.e., has significant cognitive value) to the extent that it rests on practice, to the extent that it proves to be not pure but applied mathematics. Speaking for the moment in Hegelian language, *pure mathematics continually "negates" itself as pure mathematics; if it did not do so it could not have scientific significance, could not develop, could not surmount the difficulties which inevitably arise in it.*

In their formal aspect mathematical theories stand apart from their real contents as so many schema for obtaining concrete results. Mathematics emerges in this way as a method for formulating quantitative laws of the natural sciences, as an apparatus for making use of its theory, as a means for solving problems in the natural sciences and technology. The significance of pure mathematics in the present epoch resides mainly in the mathematical method. And, as every method exists and is developed not for its own sake but for its applications, in connection with the content to which it is applied, so mathematics cannot exist and develop without applications. Here again is revealed the unity in contradiction: the general method stands in opposition to the concrete problem lem as a means of its solution; but itself arises from the generalization of concrete material and itself exists, develops, and finds justification only in the solution of concrete problems.

3. Social practice plays a determining role in the development of mathematics in three respects: it poses new problems for mathematics, stimulates its development in particular directions, and provides criteria for the validity of its results.

This can be seen with extraordinary clarity in the example of the origins of analysis. In the first place, it was developments in mechanics and technology which brought forward the problem of studying the dependence of variable quantities in the most general form. Archimedes came right to the edge of the differential and integral calculus. but remained nonetheless in the framework of problems in statics, while in modern times it was precisely the investigation of motion that produced the concepts of variable and function and made necessary the formalization of analysis. Newton could not have developed mechanics without developing the corresponding mathematical methods.

Secondly, it was precisely the needs of social production which prompted the posing and the solving of all these problems. This stimulus was not yet present either in ancient or medieval society. Finally, it is quite characteristic of mathematical analysis, in its beginning, that it found proofs for its results primarily in its application. Only for this

reason could it be developed without rigorous definitions of its fundamental ideas (variable, function, limit) which were not given until later. The validity of analysis was established by its applications to mechanics, physics, and technology.

What we have said applies to all periods of the development of mathematics. Beginning with the 17th century, mechanics, theoretical physics, and the problems of the new technology exerted an especially direct influence on its development. The mechanics of continuous media and, later, field theory (thermodynamics, electricity, magnetism, gravitational fields) led to the development of the theory of partial differential equations. The working out of molecular theory, and of statistical physics in general, beginning at the end of the last century, served as an important stimulus for the development of the theory of probability, in particular of the theory of random processes. Through its analytical methods and generalizations, the theory of relativity played a decisive role in the development of Riemannian geometry.

In our time the development of new mathematical theories, such as functional analysis and others, is stimulated by problems in quantum mechanics and quantum electrodynamics, computational problems of technology, statistical questions in physics and technology, and so on. Physics and technology not only pose new problems for mathematics and direct it toward new areas of investigation, but they also provide renewed stimulus for the development of areas of mathematics originally constructed, by and large, from within mathematics, such as Riemannian geometry. Briefly, intensive development of the science requires not only that it proceed to tackle new problems but also that the necessity for their solution be dictated by the needs of the development of society. Many theories have arisen in mathematics in recent times, but only those were developed and received a permanent place in the science which found applications in natural science and technology, or which played the role of important generalizations of those theories which have such applications. Moreover, other theories which found no essential applications; for example, certain refinements of geometrical theories (non-Desarguean and non-Archimedean) have not developed further.

The truth of mathematical results is not, in the end, based on its definitions and axioms, not in the formal rigor of its proofs, but in real applications, i.e., in the final analysis, on practice.

It is necessary to understand, above everything else, that the development of mathematics is the result of the interaction of the logic of the subject matter (reflected in the internal logic of mathematics itself) with the influence of production needs and the links with natural science. This development proceeds in complex ways through the struggle of opposites and includes essential changes in the basic content and form of mathematics. With regard to content, the development of mathematics is determined by its subject matter, but it is impelled basically, and in the final analysis, by the needs of production. Such is the basic law of the development of mathematics.

To be sure, we ought not to forget that this description applies only to the basic laws and that the relation of mathematics to production, generally speaking, is complex. From what we have said above, it would clearly be naive to attempt to base the appearance of any given mathematical theory directly on "production necessities". More than that, mathematics, like every science, possesses a relative independence, its own internal logic, which reflects, as we have emphasized, an objective logic, i.e., a conformity with the laws of the subject matter.

4. Mathematics has always been influenced not only by social production, but by the whole of social conditions in their entirety. Its splendid progress in the epoch of the triumph of classical Greece, the successes of algebra in Italy during the era of the Renaissance, the development of analysis in the period after the English Revolution, the progress of mathematics in France in the period of the French Revolution—all this convincingly demonstrates the continuous connection between mathematical progress and the general progress of society technically, culturally and politically.

This pattern is also clearly exhibited in the development of mathematics in Russia. It is impossible to separate the establishment of an independent Russian school of mathematics, starting with Lobachevsky, Ostrogodsky, and Chebyschev, from the progress of Russian society in its entirety. The time of Lobachevsky is the time of Pushkin and Glinka, the time of the Decembrists, and the blossoming of mathematics was one element of a general progress.

Even more persuasive is the influence of social development in the period after the Great October Socialist Revolution, when investigations of fundamental significance appeared one after another with striking rapidity in many areas: in the theory of sets, topology, number theory, probability theory, the theory of differential equations, functional analysis, algebra, and geometry.

Finally, mathematics has always experienced and still experiences the marked influence of ideology. As with every science, the objective content of mathematics is perceived and interpreted by mathematicians and philosophers in the framework of this or that ideology.

In short, the objective contents of a science are always presented in one ideological form or another; the unity and struggle of this dialectical opposition—objective content and ideological form— play, in the development of mathematics as in every science, a role which is by no means small.

The struggle of materialism, corresponding to the objective contents of science, with idealism, at variance with those contents and distorting their ideas, goes on through the entire history of mathematics. The struggle is clearly marked out in ancient Greece, where the idealism of Pythagoras, Socrates, and Plato is projected against the materialism of Thales, Democritus, and the other philosophers who created Greek mathematics. With the development of a slave-owning order, the upper

strata of society separated itself from taking a part in production, considering that to be the destiny of the lower class; and this generated the separation of "pure" science from practice. Only pure theoretical geometry was worthy of the attention of the true philospher. Characteristically, the investigation of certain curves obtained by mechanical means, and even the investigation of conic sections, were considered by Plato to be outside the limits of geometry, since they "do not put us in touch with eternal and incorporeal ideas" but "are used as tools in low and vulgar trades".

A clear example of the struggle of materialism against idealism in mathematics is provided by the activity of Lobachevsky, who advanced and defended a materialist interpretation of mathematics against the idealistic views of the Kantians.

The Russian mathematical school generally is characterized by a materialist tradition. Thus, Chebyschev clearly emphasized the decisive importance of practice, and Lyapunov expressed the approach of the native mathematical school in the following remarkable words: "The more or less general path of theory is the detailed investigation of questions which are of particular importance from the point of view of applications and at the same time present special theoretical difficulties demanding the investigation of new methods and the construction of new scientific principles, and the subsequent generalization of these results and constructions by means of more or less general theory." Generalization and abstraction, not for their own sake but in relation to concrete material; theorems and theories, not for their own sake but in general relation to science, leading in the final analysis to practice—this, indeed, proves to be what is important and rewarding in the whole undertaking.* Such were the aspirations of Gauss and Riemann and other great scholars.

However, with the development of capitalism in Europe, ideological points of view began to work a change in the materialist viewpoint which had reflected the dominant ideology of the expanding bourgeois epoch of the 16th to early 19th centuries. Thus, for example, Cantor (1846-1918), creating the theory of infinite sets, appealed openly to God, declaring in this spirit that infinite sets have absolute existence in the divine intellect. Poincaré, the outstanding French mathematician of the late 19th and early 20th centuries., advanced the idealist notion of "conventionalism", according to which mathematics consists of conventionally agreed-upon schema, taken for convenience as the description of a many-faceted experience. Thus, in the opinion of Poincaré,

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*** A general understanding of the necessary connection of the different areas of mathematics with each other and with natural science and practice has enormous significance not only for a correct view of mathematics but also for orienting the investigator in the selection of direction and subject of research.**

the axioms of Euclidean geometry are no more than agreed-upon conventions, significant because of their clarity, convenience, and simplicity, but which do not conform with reality. For this reason, Poincaré said, physics, for example, would sooner give up the law of rectilinear propagation of light than it would give up Euclidean geometry. This point of view was refuted by the development of the theory of relativity which, despite all the "simplicity" and "convenience" of Euclidean geometry, led to the result in complete harmony with the materialist ideas of Lobachevsky and Riemann, that the real geometry of space is non-Euclidean.

A variety of tendencies appeared among mathematicians at the beginning of the 20th century as a result of the difficulties arising from the theory of sets and in connection with the necessity for an analysis of the fundamental concepts of mathematics. Agreement was lost as to the way in which the content of mathematics should be understood; different mathematicians came not only to look upon the general foundations of the science in different ways, as had previously been the case, but arrived at different evaluations of the meaning and significance of individual concrete results and arguments. Deductions which were considered meaningful and interesting by one mathematician were declared by another to be devoid of meaning and significance. There arose the idealist currents of "logicalism", "intuitionism", "formalism", etc.

Logicalism asserts that the whole of mathematics is a consequence of the ideas of logic. Intuitionism sees in intuition the source of mathematics and considers only what can be apprehended intuitively to be meaningful. In particular, therefore, it completely denies the significance of Cantor's theory of infinite sets. More than that, intuitionists deny the simple meaning even of such assertions as the theorem that any algebraic equation of nth degree has n roots. For them, this assertion is empty since the method of computing the roots is not indicated. Thus the complete rejection of the objective meaning of mathematics led intuitionists to denigrate as "devoid of meaning" a significant part of mathematics.

The most outstanding mathematician at the beginning of our century, D. Hilbert, undertook to save mathematics from assaults of this type. The essence of his idea was to try to reduce mathematical theories to purely formal operation on symbols according to rules agreed upon previously. The argument was that, in a purely formal approach, all the difficulties would be removed since mathematics would then become the symbols and the rules of acting upon them, without any reference at all to their meaning. This, then, is the aim of formalism in mathematics. According to the intuitionist Brouwer, the truth of mathematics for the formalist exists on paper while for an intuitionist it is in the head of the mathematician.

It is not difficult, however, to see that they are both incorrect, since mathematics, in addition to the fact that it is written on paper and the

fact that it is thought by mathematicians, reflects reality, and the truth of mathematics includes within itself the correspondence to objective reality. By divorcing mathematics from material reality, all these tendencies turn out to be idealist.

Hilbert's idea was refuted as a result of its own development. The Austrian mathematician Gödel showed that it is impossible to formalize even arithmetic completely, as Hilbert had believed. Gödel's result clearly revealed the internal dialectic of mathematics, a dialectic which does not permit us to exhaust even one area by formal calculation. Even the simplest infinity, that of the sequence of natural numbers, turned out to be an inexhaustible, finite schema of symbols and their rules of operation. Thus was proved mathematically what Engels had already expressed in a general way when he wrote: "Infinity *is* a contradiction... The removal of the contradiction would be the end of infinity." [*Anti-Duhring,* p. 59.] Hilbert had counted on being able to contain mathematical infinity within the framework of a finite schema, thereby resolving all contradictions and difficulties. This turned out not to be possible.

Under conditions of capitalism, however, conventionalism, intuitionism, formalism, and similar currents are not only preserved but supplemented by new variations of the idealist views of mathematics. Theories related to the logical analysis of the foundations of mathematics are essentially used in several new variants of subjective idealism. Today subjective idealism makes use of mathematics, especially mathematical logic, as well as physics, and for this reason, questions of understanding the foundations of mathematics assume a particular acuteness.

Thus, the difficulties of the development of mathematics under the conditions of capitalism beget an ideological crisis in this science, similar to the crisis in physics, the nature of which was explained by Lenin in his brilliant work, *Materialism and Empirio-Criticism.* The crisis does not at all mean that mathematics in capitalist countries is completely arrested in its development. Many scholars who have assumed clearly idealist positions are responsible for important and at times outstanding successes in the solution of concrete mathematical problems and in the development of new mathematical theories. It suffices to refer to the brilliant development of mathematical logic.

The radical defect of the mathematical views propagated in the capitalist countries lies in their idealism and metaphysics: separating mathematics from reality and neglecting its real development. Logicism, intuitionism, formalism, and other similar currents single out one or another aspect of mathematics—its relationship to logic, its intuitive clarity, its formal rigor, etc.—groundlessly exaggerating and absolutizing its meaning, tearing mathematics away from reality and losing sight of it as a whole behind a deep analysis of a single aspect of mathematics. As a result of such one-sidedness, none of these currents, for all the subtlety and profundity of their particular results, can bring us a true understanding of mathematics. In contrast to the various tendencies and shades of idealism and metaphysics, dialectical materialism considers mathematics in its entirety—and thus, as it actually exists, in all the richness and complexity of its connections and development. And particularly because dialectical materialism strives to understand the connections between science and reality in all of their richness and complexity, all the complexity of the development from simple generalizations of experience to high abstraction and from them to practice, precisely because in its very approach to science it remains in constant correspondence with its objective content and its new discoveries, therefore, and in the last analysis, only because of this, it is the only authentic scientific philosophy leading to the correct understanding of science in general and mathematics in particular. □

Literature

On general problems of mathematics the reader is referred to the following articles in *Bol'shaya Sovetskaya Entsiklopediya* [not yet available in English]:

Kolmogorov, A.N., *"Matematika"*. v. 26.
Aleksandrov, A.D., *"Geometriya"*. v. 10.

APPENDIX

Editorial comment on the AMS and political censorship *within* science

Interest stirred around the mathematical world with the 1964 Moscow publication of a book *Mathematics: Its Content, Methods, Meaning.* Everyone agreed that it was a major contribution to communication with the non-mathematician, the collective triumph of 25 creative Soviet authors and editors, each well known to the world community of mathematicians.

No doubt the shock effect of Sputnik, beeping overhead in 1957, helped to get the book translated and published here in 1963 by the American Mathematical Society with support from the National Science Foundation. The English-language version created more excitement and MIT bought the rights, issuing a handsome three-volume edition that proclaimed on the jacket: "There is no work in English that compares with this major survey of mathematics." A thoughtful foreword by the AMS translation editor praised the expository achievement of the Soviet authors and quoted American mathematicians on its great usefulness not only to lay intellectuals but also to scientists and even other mathematicians.

Few were aware that, by omitting two key sections from Chapter I, the AMS translation had eliminated from this work all discussion of the Marxist philosophy and every mention of the Marxist classics that had provided much of the basis for the expository power of the Soviet authors. Also suppressed, of course, was some trenchant criticism of idealist trends in Western mathematics. A careful reading of the chapter as a whole shows that omission of these two sections was not a mere editorial deletion of redundant material but an outrageous abridgement of the readers' right to know, and to judge independently, the philosophical generalizations and summations that clearly had been planned as an integral part of what the author had to say.

Only a quiet footnote at the end of Chapter I acknowledged that two sections had been omitted "in view of the fact that they discuss in more detail, and in the more general philosophical setting of dialectical materialism, points of view already stated with great clarity in the preceding sections." We suggest that the interested reader personally compare the two sections published here with the seven sections of the AMS version to see exactly how much suppression has been concealed by this seemingly candid footnote.

It is important to place responsibility correctly for such a covert and insidious act of censorship by an important scientific society, with all the attendant and inescapable political implications. No doubt personal responsibility attaches to S.H. Gould, the official AMS translation editor. But events have shown that the leadership of the AMS itself bears the primary responsibility. This became explicit after the matter was brought before the AMS Council at its meeting of 15 August 1977 by Judy Green of Silver Spring, Maryland, then a member of the Council.

Reportedly, at that meeting the Council seemed to agree with Professor Green that the omission constituted political censorship and should be corrected. But action was postponed until the Council meeting of 3 January 1978 at which the Executive Committee recommended, on the basis of a split vote, that the AMS not translate the two omitted sections because of 1) the difficulty of distributing such a translation to the purchasers of the book and 2) the question of "whether in a changed political climate the author would want to have it translated". The AMS Council agreed, though neither of these trivial arguments addressed the central question of political censorship that deprived AMS members and others of the right to decide for themselves on the philosophical questions dealt with in the omitted sections.

The matter was not brought out in the open until Green wrote a letter [AMS *Notices* 25 (4): 240, June 1978] pointing to the responsibility of the AMS which officially handled the translation and took out the copyright. Her letter stressed the importance of correcting an action that reflected the redbaiting atmosphere of the McCarthyite 1950s, as a result of which some AMS members are still unemployed. Green ended by expressing the hope that the Council would reverse itself and publish the omitted sections in the AMS *Bulletin* since she had found that many colleagues would like to read the material in translation.

We hope that word gets around on the availability of these two essays in *Science and Nature* though we think it would have been far preferable that the AMS had demonstrated its integrity by doing the translation and publishing. And we hope that the AMS members will not let the censorship issue be forgotten. The following questions might be addressed quite forcefully to the AMS leadership: Why was an act of censorship upheld that violates every tradition of free scientific inquiry? Why was the mathematical community not permitted to judge for itself the merits of the Marxist philosophical ideas expressed in these two essays? Does not professional *self-censorship* of this kind contribute objectively to the current rightist efforts toward reviving McCarthyite war hysteria? □

Grandmother resolves a contradiction

On this theme of division there is a humorous question which is extraordinarily instructive. Grand mother has bought three potatoes and must divide them equally between two grandsons. How is she to do it? The answer is: make mashed potatoes.

The joke reveals the very essence of the matter. Separate objects are indivisible in the sense that, when divided, the object almost always ceases to be what it was before, as is clear from the example of "thirds of a man" or "thirds of an arrow." On the other hand, continuous and homogeneous magnitudes or objects may easily be divided and put together again without losing their essential character. Mashed potatoes offers an excellent example of a homogeneous object, which in itself is not separeted into parts but may nevertheless be divided in practice into as small parts as desired. Lengths, areas, and volumes have the same property. Although they are continuous in their very essence and are not actually divided into parts, nevertheless they offer the possibility of being divided without limit.

Here we encounter two contrasting kinds of objects: on the one hand, the indivisible, separate, discrete objects; and on the other, the objects which are completely divisible, and yet, are not divided into parts but are continuous. Of course, these contrasting characteristics are always united, since there are no absolutely indivisible and no completely continuous objects. Yet these aspects of the objects have an actual existence, and it often happens that one aspect is decisive in one case and the other in another.

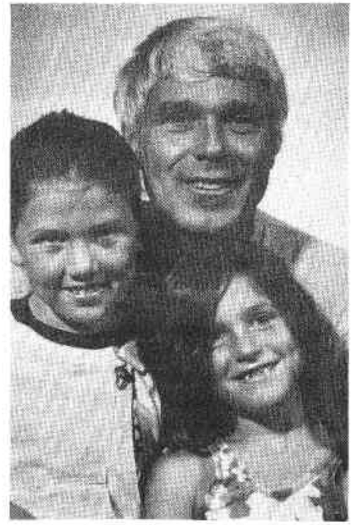
In abstracting forms from their content, mathematics by this very act sharply divides these forms into two classes, the discrete and the continuous.

The mathematical model of a separate object is the unit, and the mathematical model of a collection of discrete objects is a sum of units, which is, so to speak, the image of pure discreteness, purified of all other qualities. On the other hand, the fundamental, original mathematical model of continuity is the geometric figure; in the simplest case the straight line.

-- Aleksandrov, Kolmogorov and Lavrent'ev, *Mathematics: Its Content, Methods, and Meaning.* MIT Press 1969, p. 32.

A science historian on the utility of Marxist philosophy and its relation to science

Dialectical Materialism in Modern Biology



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Introduction

Because dialectical materialism is a valuable approach to investigating nature, it is also a valuable way of teaching about nature. In the following essay, I use examples from several areas of modern biology to illustrate how the dialectical method can be useful in understanding and teaching contemporary science. For each example, I will contrast the dialectical approach to the more frequently encountered mechanistic and sometimes even idealistic approaches which abound in much of the current (especially textbook) literature. I will also show how this Marxist view develops out of natural science rather than being imposed on it.

The history of biology, like that of the other sciences, has been characterized by a gradual but ever-increasing move away from explanations based on philosophical idealism; the last century and a half has seen an important qualitative shift to non-idealistic (mostly materialistic) explanation.

Idealistic explanations dominated much of ancient (Egyptian, Greek and Roman) biology, though some elements of materialistic explanation were present (e.g., Epicurus, Lucretius, some of Aristotle on biology). Idealism persisted into the nineteenth century as a major basis for explanatory models in many areas of biology. In embryology, for example, idealism showed itself as the preformation theory—the idea that every egg or sperm contained a miniature, "pre-formed" individual of the species, whose embryonic development consisted only of quantitative changes both in size and proportion. In taxonomy, idealism showed itself in the doctrine of types (what Ernst Mayr has called typological thinking) and the concept of the immutability of species. In both cases, species were thought of as fixed and unchanging entities derived essentially from the mind of the Creator. The doctrine of immutability and typology extended into and dominated the early history of comparative anatomy, particularly in the "idealistic morphology" (as it was actually called) of Georges Cuvier in France and Richard Owen in England. In evolution, idealism was visible in Lamarckism, Neo-Lamarckism, orthogenesis, aristogenesis and other theories which hypothesized directionality and purpose (teleology) in the history of life on earth. In the study of animal behavior idealism was rampant in the form of anthropomorphism, in a strong reliance on instinct theory to explain the origin of all *basic* behaviors, and in the oft-quoted notion of a basic "human nature".

Idealism began to give way to philosophical materialism in the mid-nineteenth century, starting with physiology (Helmholtz, DuBois-Reymond, Molschott and others) and later in embryology, heredity, and finally evolution. This early materialism was largely mechanistic, but by the early-to-mid-twentieth century elements of a more dialectical materialism could be seen emerging. The examples that follow are intended to show how the basic philosophical underpinnings of biological science have been slowly evolving toward a materialist, and more specifically, a dialectical materialist stance. [More detailed discussion of this historical development is given in Allen 1978a.]

For the benefit of those not familiar with the philosophical problems of modern biology, I will first summarize and contrast mechanistic and dialectical materialism to provide a brief working definition of each viewpoint (Table I).

Mechanistic materialism tends to seek understanding of any phenomenon by studying its individual parts in isolation, reconstructing the whole as a sum of these parts (and nothing more). Mechanists thus strive to characterize each part in and of itself, failing to give due importance to the complex interaction of parts. Of course, practical reality often dictates that in biology, or any science, parts must be studied one at a time if any meaningful information is to be obtained with the methods available; a biologist who studies a single enzyme system or a single neuron is not necessarily a mechanist in philosophy. But the biologist who works exclusively with isolated systems, paying only lip service to the relation of those systems to the whole, or who believes that the whole is knowable merely as the sum of the individual parts, is basically a mechanist.

Mechanistic materialism has often been associated with the methodology of reductionism. Reductionism is the view that the most thorough understanding of any phenomenon occurs when that phenomenon can be broken down—reduced— to its lowest (accessible) level of organization. A reductionist approach to a machine would seek to reduce its operation to a few basic principles of levers or cogs interacting in precise ways. A reductionist approach to a cell would be to break it down to its organelles or, better yet, to its atoms and molecules. Although reductionism is not associated exclusively with mechanistic materialism, in the history of biology the two have usually gone hand in hand.

TABLE 1. Comparing Mechanistic and Dialectical Materialism

MATERIALIST PRINCIPLES

Matter is primary
Matter (material conditions) determines perception of reality
A material reality outside of human beings does exist
Objective knowledge of material reality is possible

MECHANISTIC MATERIALISM	DIALECTICAL MATERIALISM
The parts of a complex whole are separate and distinct	The parts of a complex whole are all interconnected
Study of a whole proceeds by study of individual parts	Study of a whole proceeds by study of individual parts and their interactions
Whole is equal to the sum of its individual parts (and no more)	Whole is equal to more than the sum of individual parts (parts + interactions)
Changes are impressed on an object or process by outside objects or forces	Processes are constantly changing and developing
	Changes originate from built-in contradictions, interacting with external objects and forces
	Quantitative changes lead to qualitative changes
	Knowledge itself is a process; material reality is knowable to some degree (but not a final degree)

Dialectical materialism holds that the study of isolated parts is not the most complete way to comprehend reality, that the whole is equal to more than the sum of its parts, though this is not seen as the result of some mysterious vitalism or unknowable force; what is important is not simply the sum total of the individual parts, but how they interact. Dialectical materialists maintain that one of the characteristics of parts is the nature of their interaction with other parts of the whole, and that, in fact, one cannot know about the part without knowing about its interactions, because they, too, help define its character. Thus, while dialectical materialists do not disparage studying parts in isolation, they also seek to study those parts in the context of the whole to which they belong. For example, a dialectical materialist might study a single nerve cell *in vitro* to determine its responses, but would not claim that this provides any necessary insight into how the nerve cell operates within the intact organism. Further study of nerve bundles, synaptic patterns, nervous system and body fluid interaction, and hormonal balance would be necessay before any picture could emerge of how nerves function in their biological (real-life) setting.

One of the most important points of comparison between mechanistic and dialectical materialism concerns the nature of development and change within systems or between systems and their surroundings. Mechanistic materialists do not deny the existence of change in the world (and thus fundamentally differ from philosophical idealists). However, the processes of change, according to mechanistic materialists, are often repetitive and/or non-developmental, treating the universe as static overall, though undergoing constant localized change. In addition, mechanistic materialists see change primarily as the result of actions impressed upon a given system by outside objects and forces. The billiard ball model of physics is a good example of the mechanistic notion of change: a billiard ball is moved not because of internal properties or processes within itself, but rather because it is hit by another billiard ball (or by a cue stick) from the outside.

The dialectical materialist's viewpoint, by contrast, emphasizes the processes of constant change and development within the universe. Organisms are born, mature, deteriorate, and finally die. Although small differences between them may be apparent, regularity or even predictability is dominant in the developmental processes of real organisms. On a larger scale, species in populations undergo developmental processes—what we call evolution. According to dialectical materialists, developmental processes are not merely the result of systems interacting with forces or other systems outside of themselves, but are directed, to a large extent, by processes, the so-called contradictions, or contradictory tendencies, within each system itself. Organisms grow because the processes of anabolism (biochemical synthesis) exceed those of catabolism (biochemical degradation). Aging, deterioration, and death occur when forces of catabolism gain ascendency over those of anabolism. Both anabolism and catabolism are internal processes, built into the living organism. Taking into account internal properties, especially their contradictions, is the key notion of the dialectical materialist view of change that most sharply distinguishes it from the mechanistic materialist view.

It is important to keep in mind that dialectical materialism does not deny the influence of external factors on changes, even on the developmental process in any given, localized system. For example, an organism may be killed in the prime of its life, before the catabolic processes gain ascendency over the anabolic. This may be due to a purely accidental process impressed on the organism from the outside (for example, it falls into a hole or is eaten by a predator). But, overall, the sum total of changes in any system, given a statistically significant sampling, would emphasize the internal as opposedto the external or accidental

factors in determining the overall direction of development.

In their emphasis on developmental and directional change, dialectical materialists are often accused of simply reflecting mid-nineteenth century faith in progress, a progress specifically fostered by the rapid growth of science at the time. However, the notion of developmental change must be distinguished sharply from the naive belief in natural and historical progress *per se.* It must also be sharply distinguished from any notion of pre-set or teleological processes. Modern biology offers examples of each of these forms of development. Embryonic development is directional and teleological, whereas evolutionary development is not. Embryos grow into adults, undergo senescence, and die in a way that is programmed specifically into the species. Interactions between the organism and its environment can extend or limit the time, and, to some extent, influence the quality of that development, but the various life stages characteristic of each species are programmed into the organisms from the moment of fertilization onward. There is an end in sight and it is pre-set from the beginning. This is truly teleological development.

The evolutionary process is also developmental and directional but non-teleological. Given a sufficiently complete fossil record, it is possible to retrace the exact pathway of historical development (what biologists call phylogeny) of any given species or group of species. However, the direction and final end point of that ***historical*** development could not have been predicted from the beginning or at any stage along the way. Dialectical materialism can account for both teleological and historical forms of development while clearly making a distinction between them. Such a distinction was not easy from the mechanistic materialist point of view, as can be seen in the inordinate amount of confusion among biologists in the early part of the twentieth century when they tried to deal with the problems of evolution, specifically adaptation, without becoming teleological. Some biologists, unable to grasp the dialectical concept of historical development, argued that the Darwinian theory of natural selection, based on notions of chance variation and random selection through interaction with the environment, could not account for the origin of adaptations [Allen 1978b], *e.g.,* an eye would have to be pre-programmed to be a fully functional eye before it could have any selective advantage.

An important concept of dialectical materialism is that internal change is generated or propelled by opposing (contradictory) tendencies within the system itself. For example, the development of individual organisms, as pointed out above, is the result of the overall interaction of anabolic and catabolic processes, the opposing tendencies of growth and deterioration that are ever-present in living organisms. There is a constant dynamic interaction of contradictory forces operating in all systems, biological and non-biological. This is often referred to as the dialectical "interpenetration of opposites". The notion of opposing tendencies is one of the keys to understanding how dialectical materialism differs from mechanistic materialism. The latter has no formalized concept of opposing tendencies as an *inherent* part of all systems.

It is sometimes asked why systems cannot change as the result of three or more opposing tendencies rather than the classical two. In the present paper I cannot go into the question of whether the dichomotizing of opposing tendencies is more a function of formality than an actual representation of nature. But it is true that the overall direction which a developmental process takes is going to be determined, in the final result, by the interaction of the two most strongly opposed tendencies. Obviously, every living process is the result of many interacting factors, both internal and external (temperature, light, available nutrients, pH, genetic program, presence of absence of poisons, etc.). But for the purpose of understanding the overall direction at any point in time, the logic of dialectics dictates that we try to analyze this multiplicity of interactions in terms of opposing tendencies. In doing this, also, dialectical materialists take advantage of the distinction between primary and secondary contradictions, seeing some dichotomies as more generally important at a given moment in time than others.

Let us now examine some specific areas of modern biology where a dialectical approach can provide a more clear and comprehensive explanation of fundamental processes than the mechanistic approach has provided in the past.

Evolutionary Theory

If any area of biology illustrates the fact that dialectical materialism is not a philosophy imposed upon nature, but derived from it, it is evolutionary theory. This is partly because Marx and Engels were themselves highly impressed with Darwin's theory of natural selection, and to some extent modeled their view of history on it. This is also partly because evolutionary theory has accumulated such a vast quantity of data and experience that it is now well understood. The process of evolution by natural selection is dialectical because it is based upon the constant interaction of two contradictory processes within organisms: those of heredity and variation. Heredity is the faithful (exact) replication of parts, whereas variation is the unfaithful (inexact) replication of parts. Heredity is conservative (preserving what already exists) while variation is radical (replacing the old by the new). It should be obvious that without the constant of these two opposing tendencies evolution by natural selection could not occur. If all replication were exact, there would be no variation to be selected by interaction with the environment. On the other hand, if there were only variation and no faithful replication, new forms could not be preserved beyond the new generation in which they occurred. The constant development of species—the coming into being of new species and the extinction of old, which characterizes the history of life on earth—is a result of the dialectically opposing tendencies of heredity and variation, without either of which there could be no evolution.

If it is true that evolutionary development cannot occur without the dialectical contradiction of heredity and variation, it is also true that

heredity and variation make evolution inevitable. The world of life is, always has, and always will undergo continual change and development. This change is directional and non-random in the sense that it is the result of the interaction of continually acting forces. While various factors of the environment in different localities of the earth's surface may change over time, and therefore bring new outside pressures to bear on living systems, the process of heredity and variation are for the most part constant and knowable. For many genetic traits in many species we can predict quite accurately what the mutation rate will be under any given set of conditions. While accurate prediction of the course of evolution is not possible (any more than accurate prediction of human history is possible), the operation of knowable and regular forces produces certain predictable consequences. For example, we know that if the population size remains large enough, and if it harbors enough residual variability, it will be able to maintain itself for indefinite periods of time by undergoing slow but adaptive changes. Similarly, we can predict that, if a large population is divided into two or more geographically isolated populations, after a period of time those two will accumulate enough different variations so that they may no longer be interfertile.

It is often asked of dialectical materialists, in relation to the evolution of biological species or the development of human history, why there won't be an end to all development. Is there not an ideal society, or a perfectly adapted species somewhere in our future? The answer is obviously no. With regard to evolution, it is important to keep in mind that perfected, and therefore non-changing, adaptation is never possible. Populations of organisms interact with their environment. As the organisms adapt more successfully to the environemnt, they are able to exploit its potential resources more effectively (in one way or another, that is what adaptation is all about) and thus bring about changes in that environment. An example is the proliferation of marsupials throughout Australia in the last 30-35 million years that distinctly altered aspects of the continent's ecosystem, particularly through overgrazing by kangaroos. This, in turn, has affected the spread of other species, including our own. Thus, adaptation is a continual and never-ending process of interaction; constant dialectical contradiction between the internal and the external—the organism and its environment—which insures that change will never cease.

The process of evolution also illustrates clearly the way in which quantitative changes lead to qualitative changes. Consider an initial population which becomes subdivided, through geographic isolation, into two separate populations. At first, the two populations are interfertile and, by any definition, still members of the same species. As time goes on, the randomness of variation (mutation) inevitably produces the accumulation of many differences between the two populations. For example, one population, let us say of deer mice, may evolve increasingly longer tails, the other increasingly shorter tails. These are quantitative changes in a single character. At the same time, one population may be showing changes in one trait such as ear size, whereas the other may show variation in a quite different trait, such as coat color. But, so long as these differences remain only quantitative in nature and the two populations, if brought back together again, can still manage to produce fertile offspring, they are considered subspecies or varieties of the same species. However, if isolation persists for long enough, the two populations may accumulate enough behavioral, anatomical and/or physiological differences to make successful interbreeding impossible. At this point the quantitative changes have accumulated to such a degree that we say a qualitative difference exists: the two groups are now separate species. By almost any biological definition, the two species would be considered qualitatively distinct from one another. It may be objected that calling the difference at the species level qualitative and that at the subspecies level quantitative is arbitrary. However, by any *biological* criterion of species, this objection would not hold up. In the most fundamental biological sense—that is, in terms of reproductive compatibility—the difference is no longer simply one of *degree* but of *kind;* reproductive incompatibility has been achieved and the two species must henceforth develop along separate and diverging lines.

The evolutionary process can also be useful for illustrating an aspect of dialectical materialism which is often confused in discussing human politics: the relation between evolution and revolution. As the term is ordinarily used, evolution is a process involving both quantitative change and qualitative transformation. Gould's [1979] notion of punctuated equilibrium, i.e., of rapid and significant changes in evolutionary rate, refers to the stage of qualitative transformation in the evolutionary process. It is important to note that revolutions cannot take place without prior quantitative development, nor in general could evolution proceed without some degree of revolutionary development. In biology, evolution often involves sudden revolutionary processes. For example, the rapid evolution (adaptive radiation) of the marsupials in Australia could only have followed the revolutionary event characterized by the invasion of a new and relatively isolated continent by primitive mammals from the Asian mainland. That invasion itself was the result of gradual quantitative changes (slow continental drift along with slow but continuing animal migrations). After the invasion of Australia and gradual adaptation to its varied ecological niches, further evolutionary diversification of species could occur. In natural and human history, the question is not one of *either* gradual evolution *or* sudden revolution. The processes of slow quantitative change and sudden qualitative transformation occur throughout all historical change.

Ecology

As the sciences of ecology and evolutionary biology are intimately connected, the line between them is often drawn arbitrarily. Certain topics, however, clearly fall into the province of ecology. One of these is the process of succession. The development of this concept, since it was introduced early in our century, illustrates clearly the difference between a mechanistic and a dialectical approach to biological processes.

Succession is usually defined as the regularized sequence of biological communities which replace one another in a given geographical area over time. One classical example of succession, found in most textbooks, traces the development of communities from a sandy lake shore to the establishment of a hardwood forest. This succession occurs in highly predictable stages. For example, a sandy beach is gradually invaded by grasses, the first plant life to establish any kind of permanent foothold. Short scrubby grasses are usually replaced by taller more luxuriant grasses, and these eventually by fast growing shrubs and small trees such as cottonwoods or willows. Eventually the willows and grasses are replaced by scrub pine and later by larger conifers. The coniferous forest is eventually replaced by an oak or oak-hickory forest which in some localities (for example, the midwest) is called the climax community; in other areas the coniferous forest is replaced by beeches and maples (which become the climax community). Now the process of succession itself is a very clear illustration of dialectics in action. Sand is very difficult for plants to gain any kind of foothold in, largely because it is so loose and (as a result) holds little water. The widespread and diffuse root systems of grasses however, can make some inroads into sandy soil. As a result, their root systems hold the soil together and retain water more effectively. Gradually, as more grasses establish themselves, they bind the soil more firmly, chemically and physically breaking it down into smaller particles and changing its chemical nature by the decomposition of their organic parts. The changes brought about by the grasses make it possible for seedlings of plants such as cottonwoods and willows to take hold. These trees require a great deal of sunlight for germination of their seeds, but once established as saplings are well adapted to grow in loose sandy soil. Their root systems are diffuse (like the grasses), and thus can absorb water before it soaks through the loose soil deep into the ground. Willows and cottonwoods are also fast growing, and consequently attain maturity in a relatively short period of time. Like grasses, fast growing softwoods further alter the soil, making it possible for the seedlings of conifers, particularly pines, to take hold. Conifers also require a great deal of sunlight for germination. However their root systems are deeper and consequently can make contact with lower lying levels of water to maintain themselves through greater periods of drought and environmental stress. Conifer communities are therefore more long-lasting than either grass or cottonwood-willow communities.

As the conifer forest grows, however, it becomes the victim of its own internal contradiction. Conifers shade the ground, and therefore make it increasingly difficult for their own seedlings to become established. The seeds of hardwoods, on the other hand, are able to germinate quite successfully in shady spots. Therefore in the shadow of large conifers, the small saplings of hardwoods begin to take over. Gradually the hardwoods replace the conifers, and a "climax community" is established. Even in this rather classical description of succession, it should be clear that the process is a developmental one, spurred on by the constant interaction between organisms and their physical environment, and by contradictory tendencies within the populations of organisms (communities) themselves. As each community establishes itself, it sets the stage ultimately for its own replacement.

The dialectical approach to ecology raises a very important question about the so-called final or "climax" stage of succession. The more mechanistic ecologists of the 1930s and '40s tended to see the climax community as a final, stable development, the end of regularized change. Most would have agreed with Kormondy's [1969, p. 158) view:

> If this is so, then why eventually does an ecosystem achieve a kind of steady-state? This is a condition referred to as a climax community, an ecosystem that is self-perpetuating and in which the dynamic changes not only occur, but are necessary for the maintenance of the community. ... The climax community results when no other combination of species is successful in outcompeting or replacing the climax community.

However, in the 1960s and 1970s ecologists gradually abandoned or at least greatly modified the climax concept, seeing even these supposedly stable communities as also undergoing continual developmental changes—only more slowly than any of the earlier stages. As mentioned above in discussing evolution, organisms are constantly affecting and changing their environment. Even though the rate of change may be slower, a so-called "climax community" is inevitably producing alterations in the environment. This, in turn, affects the kinds of communities and species which can inhabit the area at a later time. Thus, like human history or the evolution of species on earth, there is no final or ideal state in ecological succession. The "climax community" is only a figment of our imagination, the result of imperfect knowledge and an imperfect (mechanistic) viewpoint regarding environment-community interactions.

Adopting a consciously dialectical view of nature would make any ecologist, however inexperienced with specific ecosystems, suspicious of theories of ultimate stability, or of non-changing systems. Again I emphasize that this is not a matter of imposing a philosophical viewpoint upon nature, but of deriving a philosophical viewpoint from nature. The more we come to know about natural systems, biological or otherwise, the more nature tells us that nothing remains stable and unchanging.

Genetics

The science of genetics, like that of evolution and ecology, provides illustrations of dialectical processes. As all Marxists know from the Lysenko catastrophe in the Soviet Union in the 1930s and '40s, the field of genetics has been rampant with philosophical debates between idealists, mechanists, and dialecticians for over fifty years. This is not the place for detailed discussion of the Lysenko controversy, but it must be pointed out that Lysenko was wrong in claiming that his concept of modification of the organisms by the environment was more

materialistic and dialectical than the classical concept of the "gene"; it was in fact just the opposite. Lysenkoism was able to grow and flourish for a period of time in the Soviet Union because of the failure to apply dialectical materialism rigorously and consistently to studies of heredity. There is hardly anything idealistic or non-dialectical about modern Mendelian or molecular genetics.

Along with evolution, genetics demonstrates clearly the contradiction of heredity *versus* variation. Unique, however, are the dialectical aspects of genetics relating to the potential and the actual. The study of genetics today encompasses two broad and complementary processes. One is the *transmission* of hereditary information (the genetic code) from one generation to the next; the other is the *translation* of genetic information in the fertilized egg into adult characteristics (ontogeny). The gene is thus involved in a dual process: it must maintain its own integrity, its own potentiality, as a code, from generation to generation. At the same time, that code must be translated into *actual* physical and biochemical structures during development (proteins, enzymes, and ultimately organelles, cells, tissues and organs).

During the early part of our century, there was considerable debate among biologists and physicists as to what kind of substance genes could be made of that would allow their faithful replication and transmission from one generation to the next, yet also allow them to guide the formation of individuals through the embryonic process. The obvious success of the Watson-Crick model of DNA reflected its ability to account for both these processes by the same molecular structure. The double helix can unwind and faithfully replicate itself during the transmission process. It can also unwind and guide the formation (through transcription and translation) of the multitude of traits which come into being during embryonic development. Moreover, the Watson-Crick model also allows for further elaboration in our understanding of genetic control mechanisms. The work of Monod and Jacob [1961a], developing the operon and associated theories, was an extension of and compatible with, the basic Watson-Crick model. Thus, employing the known biochemistry of protein synthesis, both genetic transmission and translation (the *potential* and the *actual*) aspects of the gene as a structural and functional unit could be explained.

In the history of classical Mendelian genetics a number of problems have arisen where a dialectical viewpoint could have, and finally did, clarify basic principles. There is little doubt that in the early days of the Mendelian chromosome theory, as enunciated by T. H. Morgan and others between 1910 and 1920, genetics had a strongly mechanistic bias [Allen 1978b, esp. chs. 5 and 8]. The initial conception of a chromosome was like a string of beads, with each bead representing a separate and distinct, atomistically-conceived gene. A predominant concept at the time was that of the gene as the determiner of a single trait (what was called the "one gene, one trait" concept). There was little concept of interaction between genes. The gametes were considered a mosaic of genes, and the adult organism a mosaic of traits. Only gradually did it become clear that neither at the genotypic or phenotypic level is an organism a mosaic of individual genes or traits. This clarity began with three discoveries: the position effect (the notion that the actual location of a gene on a chromosome, including what genes reside on either side of it, affects the way the gene is expressed as an adult character); pleiotropy (the notion that one gene may have several quite different phenotypic effects); and epistasis (the idea that, when two genes are brought together in the same zygote, they can produce a completely different phenotypic effect than either gene by itself.

Thus we began to learn the dialectics of gene expression in the developmental process and to see the adult organism as the result of complex interactions in which genotypic potentiality is translated into phenotypic actuality. But the early period of Mendelian genetics was largely limited to study of only genetic potential, *i.e.*, the *potential* of a transmitted code for interacting with cell components to produce a phenotype. Not until the 1940s, with the advent of biochemical genetics in the work on Neurospora of Beadle and Tatum [1941] and that of the phage group [*cf.* Olby 1974 and Judson 1979], culminating in the Watson-Crick model of DNA in the early 1950s, did the other dialectical aspect, genetic *actuality*, achieve equal status.

Biochemistry: Enzymes and Their Kinetics

For a final example I will consider the more chemical side of biology: the study of biochemistry, particularly that of enzymes, their structure and function. Probably no area of modern biology has shown such a sharp change in underlying philosophical position in recent years as that in enzyme chemistry.

Twenty or thirty years ago the mechanistic viewpoint predominated in enzymology. For example, biochemists tended to break down complex systems (cells with their highly organized internal structure and chemical compartmentalization) into isolated parts. Single enzymes were studied *in vitro,* isolated from all other cell components of this complex interacting system. A by-product of this approach was that the process of enzyme extractions and isolation tended to produce highly concentrated solutions, many thousands of times greater than that found in living cells. Studies of such solutions produced a variety of generalizations about the way enzymes interacted with their chemical substrates (a set of theoretical constructs referred to as enzyme kinetics). So apparently successful were these studies that, from the 1930s to 1950s, many biologists and biochemists spoke of cells as nothing but bags of enzymes. Such a mechanistic concept failed to take into account the organizational properties of enzymes as molecules in their own right. It also obscured the relationship between enzymes and sub-cellular biological structures, for example, the binding of enzymes to membranes and their compartmentalization within cells. It tended to obscure the differences which might exist between the kinetics of highly concentrated, as compared to highly dilute solutions. Furthermore, it obscured the interaction which occurs between enzyme systems, in everything from enzyme induction

to the complex interconnections between metabolic pathways. The mechanistic view obscured the fact that the function of enzymes is very much affected by whether they are free floating in the cell cytoplasm or bound to cell structures. Indeed, in recent years the whole study of biological transport (the movement of materials back and forth across membranes) has been revolutionized by recognition of the role of bound enzymes within the membrane structure.

Today we recognize a number of more dialectical aspects of enzymes and their interconnections through metabolic pathways. One of the most interesting is the notion, first enunciated by Monod and Jacob [1961b] of enzyme induction, that is, regulation at the genetic level of enzyme synthesis by the cell's metabolic needs. In certain strains of bacteria, for example, the enzyme β–galactosidase (which breaks down lactose, or milk sugar) is always present, whether or not lactose is available in the culture medium. In other strains, however, β–galactosidase is present only after the cells have been incubated in a culture medium containing lactose. As Monod and Jacob [1961b] concluded, the presence of substrate can *induce* the synthesis of enzyme; the lack of substrate represses the synthesis of enzyme. In the older mechanistic model of the cell as a "bag of enzymes", the enzyme was either present or not, at all times. The more subtle control process of induction showed that cells were capable of complex feedback mechanisms in which the internal and external influences were in constant dialectical interaction.

Another interesting example comes from the process of developing theories for how enzyme molecules interact with the molecules of their substrate. A so-called lock-and-key model, developed about 1940, pictured the enzyme and its substrate fitting together with a complementary physical structure, much as a key fits into a lock. Though it was always somewhat confusing as to whether the enzyme was the lock and the substrate the key or *vice versa,* the utility of the model lay in its physical emphasis on the complementary structural relationship between enzyme and substrate molecule. In a very simplified way, the lock-and-key model provided a visual and mechanical analogy to understand enzyme-substrate interactions. It predicted accurately certain aspects of enzyme kinetics, and seemed to fit in well with the standard concepts of chemical kinetics.

However, further studies uncovered phenomena which the lock-and-key model could not adequately explain. The most prominent of these involved the observation that, as the end products of certain pathways accumulated, the rate of enzyme catalysis for earlier steps in the process slowed down. The slowing down was observed to occur at a rate different from that which would be predicted by standard kinetics in which the accumulation of end-products shifts the equilibrium of the reaction to the left. A number of investigators finally concluded that enzyme molecules are not rigid structures (as a lock-and-key analogy might suggest), but that they are able to shift from one structural form to another as they interact with either substrate or end-product. As end-product molecules accumulate, they interact with one active site of the enzyme molecule, shifting the molecule to a new structural form that prevents the enzyme's second active site from interacting with the substrate. This change greatly slows down the catalytic process. In the rigid, mechanistic view of the enzyme molecule, such a subtle interaction could hardly have been visualized. It is only with the rejection of the mechanistic lock-and-key model that modern biochemists began to understand dialectically the complexity and regulatory capacity of enzymes. Again, a dialectical outlook leads to asking different questions, and consequently, to developing a different understanding of nature than that prompted by a mechanistic viewpoint.

A final example of the difference between the dialectical and mechanistic materialist viewpoints in modern biochemistry is found in studies of enzyme kinetics at different concentrations. As mentioned above, classic methods in biochemistry involved extracting enzymes from tissues and studying them in very much higher concentrations than that found in individual cells. This also meant study of individual enzyme systems *in vitro*. But, as recent studies have shown, the kinetics of interaction between an enzyme and its substrate are vastly different when there are only a few hundred molecules, as opposed to hundreds of millions, concentrated in the biochemist's test tube. We now know that understanding of enzyme kinetics *in vitro,* useful as it may be, does not justify our extrapolation of those kinetics to *in vivo* conditions. There is nothing incorrect or philosophically invalid about *in vivo* studies. However, the mechanistic viewpoint, which tends to see the whole as nothing more than a sum of its parts, would tend to extrapolate from *in vitro* to the *in vivo* conditions. The dialectical viewpoint would never take such an extrapolation for granted. Let me emphasize again that the study of nature has shown that it is the dialectical, rather than the mechanistic, viewpoint which leads to the most useful insights concerning reality around us.

Conclusion

In the above discussion, I have tried to show that a consciously dialectical materialist philosophy provides a more thorough and subtle guide to the study of nature than a mechanistic viewpoint. I have also suggested that in the history of biology in the last century-and-a-half the dialectical approach has gradually emerged in a number of different fields, both consciously and unconsciously, as the more appropriate way to view living systems. It might be asked at this point whether all this is not merely stating the obvious. Is not dialectical materialism just formalized common sense? Of course, this is true. But to the extent that philosophies serve any function at all, it is to make us more conscious and more systematic in how we interpret our day-to-day experience. For precisely the reason that dialectical materialism is more commonsensical than mechanistic materialism, it is also more useful. One can find elements of dialectical materialist thought in many of the greatest biologists of the past century, even though these individuals would not have linked themselves to any particular philosophical school and might have been (or still would be) horrified to be called "dialectical materialists". To my mind, this is perhaps the most significant evidence of the essential usefulness of dialectical materialism. If many people, consciously or unconsciously, end up describing natural processes from the same general viewpoint, it seems to show that such a viewpoint, by whatever name we call it, has both validity and utility. To the extent that a philosophical viewpoint can be systematized and codified along the lines of what Marx, Engels and Lenin did with dialectical materialism, that viewpoint can be made more immediately useful in our investigations of the world. For this reason I think that our discussion of dialectical materialism, in the concrete as well as the abstract, should aim at further systematization in relation to the specific problems of natural science. In this way, it will become even more useful for understanding, and teaching the ways of the world in natural as well as human affairs. □

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The Necessity of Dialectics

The dialectics of the brain is only the reflection of the forms of motion of the real world, both of nature and of history. Nevertheless, the bulk of natural scientists are still held fast in the old metaphysical [fixed] categories and helpless when these modern facts, which so to say prove the dialectics in nature, have to be rationally explained and brought into relation with one another. And here *thinking* is necessary; atoms and molecules, etc., cannot be observed under the microscope, but only by the process of thought... Dialectics divested of mysticism becomes an absolute necessity for natural science, which has forsaken the field where rigid categories sufficed, as it were the lower mathematics of logic, its everyday weapons. Philosophy takes its revenge posthumously on natural science for the latter having deserted it; and yet the scientists could have seen even from the successes in natural science achieved by philosophy that the latter possessed something that was superior to them in their own special sphere.

— Engels, *Dialectics of Nature.* New York 1940, pp 153-155.

A useful outline for applying philosophy to natural science

BASIC CONCEPTS OF DIALECTICAL MATERIALISM

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1. There is a real world that exists independent of the perceiving mind. The aim of science is to learn the nature of the real world.
2. It is possible to obtain valid knowledge. The world is knowable.
3. Man is a part of nature. Like every other animal, his presence in the world changes it.
4. Man is unique, however, in making changes for a purpose. Man is the tool-making animal.
5. Man relates to his environment principally through production. Production is a social activity characterized by production relations that correspond to the level of the forces of production. It is the basis of the cultural superstructure.
6. Tools are detachable, disposable extensions of the bodily organs. The evolution of tools and the production relations in which they are used is the core of cultural evolution.
7. Tool-making, coordination of hand and eye, and language are inseparably related. Language makes man the learning animal par excellence, capable of passing on what is learned from one generation to the next.
8. The scientific study of nature is carried out by making changes, observing the consequences of these changes, and formulating theories to account for what is observed.
9. Every observation of the real world is affected by both the observer and the observed. Using as raw data observations in which the observer and the observed are entangled, science must find ways of discounting for the influence of the observer on the observation.
10. Science is closely linked to technology. Science serves technology, and technology serves science.
11. Technology is social and science is social. Scientific ideas, as part of the superstructure, are influenced by the basis.
12. Since science develops in a social context, careful scrutiny of all its assumptions, both spoken and unspoken, is necessary to see if they reflect an unacknowledged bias.

13. All knowledge is at best approximate and one-sided and requires constant checking by observation and experiment and is subject to revision in the light of new experience.
14. All observations of phenomena are made from a particular frame of reference and are necessarily one-sided and, to that extent, subjective. Objective knowledge is obtained, not apart from the subjective, but through it. Objective knowledge of phenomena consists of those properties revealed by subjective observations or derivable from them that remain the same if the frame of reference is replaced by any other comparable frame of reference. Hence objective knowledge is necessarily social and verifiable.
15. The growth of knowledge involves both transmitting the knowledge of the past and adding to it or correcting it. The former tends to be conservative, the latter tends to be revolutionary.
16. The world is in flux. Constant change is real and must be taken into account. But science aims to find what is permanent in the changing reality.
17. The nature or quality of an object consists of the sum total of its internal and external relations.
18. Objects are best understood in terms of their historical development.
19. A holistic, dynamical process approach is necessary in the study of complex systems in which there is movement. The whole is greater than the sum of its parts. The nature of the part is often determined by the nature of the whole and the relationship of the part to the whole.
20. New qualities may emerge. Change is not all quantitative. Quantitative change may lead to qualitative change.
21. Science recognizes no authorities. Acceptance or rejection of a proposition should depend only on evidence and logic.
22. Science requires freedom of discussion and criticism. □

Revolutionary Consciousness in Cuba

It was very noticeable in the early days of the Revolution that Blacks were making one tremendous jump forward, just like everyone else was. In 1962, I went to visit the Moa nickel mine. It was really a marvel technically, absolutely and completely automatic. The head of one of the departments there was a Black guy, who had not even had a sixth-grade education. And the reason he got the job will tell you a little about how things happened.

Nobody knew the engineering theory of how the process worked, except the Americans who put it up, and they had left. But this Black man had seen the American engineer carry out the operations, so he knew what to do. And he was the only guy who knew what to do. So he became the head of the department. At night he used to study technical journals, with the help of his kids—figuring out *why* the plant worked as it did.

-- Ed Boorstein, quoted by Terry Cannon and Johnetta Cole in *Free and Equal: The End of Racial Discrimination in Cuba.* Venceremos Brigade (GPO Box 3169, New York NY 10001) $1.50.

When scientists find relevance to social progress...

SCIENCE AND MARXISM IN ENGLAND, 1930–1945

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From June 29 to July 3, 1931, the Second International Congress of the History of Science and Technology was held in London. To the surprise of many, a large delegation from the Soviet Union attended–a delegation which included representatives from the very top of the "science and government" hierarchy. N. I. Bukharin, Director of the Industrial Research Department of the Supreme Economic Council presented a paper on "Theory and Practice from the Standpoint of Dialectical Materialism"; M. Rubinstein, Member of the Presidium of the State Planning Commission (GOSPLAN) discussed "Relations of Science, Technology and Economics under Capitalism and the Soviet Union"; and, probably the most provocative, B. Hessen lectured on "The Social and Economic Roots of Newton's 'Principia,' " in which he applied "the method of dialectical materialism and the conception of this historical process which Marx created to an analysis of the genesis and development of Newton's work in connection with the period in which he lived and worked." [1]. Within two weeks, in an amazing publishing feat, the papers appeared in English in a collection entitled *Science at the Crossroads* [London 1931].

These writings had a profound effect on many English intellectuals. Hessen's essay, particularly, challenged others to explore the relationship between the economic and social base of society and the intellectual and cultural superstructure. Robert Cohen has characterized it as "an act of liberation" [2]. Historians like Christopher Hill and Benjamin Farrington "took Hessen's essay as a pivot" and extended the Marxist analysis into such areas as the English Revolution and Greek science [3]. J. G. Crowther, a science journalist, immediately applied Hessen's method in writing *British Scientists of the Nineteenth Century* [London 1935].

Most important, perhaps, was the reaction of a group of young, left-leaning scientists, already disturbed by the failure of capitalism indicated by the world economic crisis and favorably disposed to the new social, economic, and scientific order in the Soviet Union.

John Desmond Bernal, a thirty-year-old Cambridge crystallographer just beginning his legendary career, recalled later that the Soviet presentations had convincingly demonstrated "what a wealth of new ideas and points of view for understanding the history, the social function, and the working of science could be and were being produced by the application to science of Marxist theory" [4]. Hyman Levy, a Professor of Mathematics at the Imperial College of Science and Technology, called the International Congress

> epoch-making; for the standpoint consistently adopted by [the Soviet] delegates crystallized out in remarkable fashion what had been simmering in the minds of many for some time past. What became clear was not only the social conditioning of science and the vital need for planning, for anticipating the social effects of discovery, but the impossibility of carrying this through within the framework of chaotic capitalism. What emerged afterwards was the necessity nevertheless for demanding that this impossible task be undertaken, in order to educate the great body of scientific men in the reasons for its impossibility [5].

Thus began the development of a coherent intellectual and political movement, the Social Relations of Science (SRS) movement [6]. Marxist scientists–Bernal and Levy, whom I have already mentioned, the biologist J. B. S. Haldane, Lancelot Hogben and Joseph Needham–constituted the core of the movement, although they were aided by other scientists of the left such as Julian Huxley and physicist P. M. S. Blackett. Through their prolific writings, speeches, and organizational work–and in the context of economic depression, the rise of fascism, and then world war–these SRS scientists generated an intense ferment within the English scientific community. In the words of one historian, they "seemed almost to dominate the British scientific world between 1932 and 1945" [7]. The scientific world became "a criss-cross of social study groups" [8]: undergraduates and graduates, scientists in universities and research institutes all debated the social and political responsibility of the scientists in the face of domestic and international crises. They were less concerned, as another account has suggested,

> with the theoretical implications of their work, or with trying to give it religious and philosophic significance, than with asking themselves what was the place of science in the social system. They were beginning at last to have a social conscience. A twentieth century system was developing, haphazardly and piecemeal; what form it would take and how England might fit into it was as much a scientist's business as anybody's" [9].

New organizations, like the Cambridge Scientists' Anti-War Group, formed in response to the new concerns; older ones, like the British Association of Scientific Workers, engaged in new kinds of political activity; and the established Royal Society and British Association for the Advancement of Science increasingly manifested the new activism. (The latter, for example, established a Division for the Social and

International Relations of Science in 1938.)

The SRS movement did not, of course, go unchallenged—especially in the 1940s. Nor was it easy to advance such radical views in the later Cold War atmosphere. But still, the SRS movement had a marked effect on post-World War II views concerning the relation of science to society, the role of the scientist in society, the proper extent of his or her involvement in politics, and the history of science. Neal Wood, far from a sympathizer with the SRS ideas, wrote of these English scientists that "with the exception, perhaps, of the Soviet Union, there was nowhere else a comparable movement among scientists, at least one so vigorous and influential" [10].

I want to deal here with only one aspect of this movement—the development and reception of a Marxist analysis of the historical and contemporary relationship between science and society. At the time when Hessen and the rest of the Russian delegation brought their revolutionary ideas to London, general English attitudes about the meaning of science were primarily shaped by Sir Arthur Eddington and Sir James Jeans. Best sellers like Jeans' *The Mysterious Universe* (1930) and Eddington's *The Nature of the Physical World* (1928) not only explained contemporary scientific achievements in an understandable form but incorporated them into an all-embracing philosophy.

The recent quantum mechanics revolution in physics, according to Eddington, revealed that "all was vanity, that unreason lay at the very basis of reality—in the quanta of action and the behavior of electrons" [11]. Science had made determinism untenable [12] and had placed "free will" back at center stage. Mind, not matter, was primary. Jeans asserted that "the universe begins to look more like a great thought than like a great machine." Mind is no longer "an accidental intruder," but "the creator and governor of the realm of matter" [13].

This philosophy of a meaningless, fickle universe existing only as a symbol in the Mind was unacceptable to those scientists who were listening to Hessen so attentively and who were looking to science to solve the pressing economic problems of society. They saw in such a philosophy a "flight from reality," a search for "a purely personal satisfaction in the world of emotional ideas" [14]. As Levy wrote, the philosophies of Jeans and Eddington were not "contributions to a reasoned understanding of the forces of Nature; they were not efforts, at a critical moment in world history, to concentrate the mind and brainpower of men on the vital problems the solution of which is so urgent that every ounce of thought should be directed to their analysis" [15]. Thus Levy, Bernal, Haldane and the others set out to provide a materialist philosophy for a socially relevant and activist science—in a form which was as acceptable and understandable to other scientists and the general public as was the philosophy of Jeans and Eddington. Or as they put it, they wanted to demonstrate that "science is not something mysterious but a weapon" for control over nature which "should be a mental and material possession of the

common man" [16].

In 1932, in *The Universe of Science*, the first of his many books, Levy argued that the heresies of Jeans and Eddington were caused by a fundamental misunderstanding of scientific methodology. [17]. According to Levy, science was a search for and study of "isolated systems," or useful bits of the universe. One of the primary tasks of experiment was to determine the minimal amount of the surrounding environment which must be included to keep the "isolate" neutral and therefore capable of scientific study. While there were no perfectly neutral systems in the universe, scientists tried to find or devise situations in which they were nearly so. "Properties" of the isolate were assigned which could be regarded as unchanging as long as certain parts of the environment were ignored.

Philosophers like Jeans and Eddington went astray, Levy argued, when they regarded scientific isolates as knowledge itself rather than as *paths* to knowledge. They forgot the assumptions which allowed treatment as neutral systems and endowed the isolates with lives of their own. The numbers assigned for convenience became the reality. The universe then appeared "fickle," "mysterious," "meaningless," or just a mathematical figment of the scientist's imagination; volition, it seemed had replaced the previously sought mechanical causes.

Levy went further—after having used the conception of "isolates" to elucidate the *internal* relations of science, he applied it also to the *external* relations of science, to "its connections and its roots in society of which it is an isolate" [17, p. 174]. Science could be properly understood, he claimed, only when the scientific isolate was viewed within a wider framework.

The engineer, for example, could determine the speed at which a rotating shaft flies apart—but in a wider setting, he must look at other properties, like its function in a turbine. He must ask still other questions when the previously neglected social environment is added: "What is the social function of the shaft or turbine?. . . In what way does it operate in production? Which individual, which class, which nation, which race will it serve?" [17, p. 219]. Thus, only as an internal isolate did an object of scientific inquiry have *neutral* properties. Once the external environment was taken into account, said Levy, science showed itself to be "a definite instrument serving the ends for which production is carried out" [17, p. 220]. "All attempts to isolate any aspect of it," he warned, "be it even the purest mathematics, from the social movement of which it is an integral part, can lead to nothing but false and dangerous conclusions" [17, p. vii].

Levy and the other members of the SRS movement had a special message for their scientific colleagues—who, they argued, had a unique role in bringing about revolutionary changes in society. The scientist, wrote Levy, would link scientific and social processes by producing the basic knowledge for any new social organization, and by working actively and politically with his colleagues to ensure the practical success of the new movement [18]. In the first instance, he found truth by bringing physical laws to light; in the second, he made truth by bringing social laws into being. The scientists, then, had to abandon his traditional position in the scientific laboratory and enter "the social laboratory where politics is practiced and history is made" [19].

The significance of Levy's discussion—the materialist conception of science, the dialectical view of the relation between science and society, the responsibility of the scientist for political action—was immediately recognized in England. One observer, moderate in his politics, asserted that Levy's views "should assist many scientific workers to think out their own position in relation to the changes which are being produced by the mutual reactions of science and society" [20]. Joseph Needham proclaimed that Levy's ideas, along with Hogben's *Nature of Living Matter* (1930), marked "the origin of an English neo-Marxian school of scientific method . . . a movement at least as important as that idealistic reaction of nineteenth century naturalism, of which [it is] the antithesis" [21]. Levy's later works, wrote one more reviewer, outlined "what must be the world outlook of science in the next period of its growth... [That] new outlook is not mechanistic, but dialectical" [22].

J. B. S. Haldane, the famous biologist and geneticist, also came to believe that the times required that "socialists learn science and scientists learn socialism" [23]. As the world economic crisis, the rise of Hitler, and finally the Spanish Civil War changed Haldane to a committed Marxist, he too contributed to the developing Marxist analysis of science and society. As he once wrote, "I don't believe in the absolute truth of Marxism in the way that some people believe in religious dogmas. I only believe it is near enough to the truth to make it worth while betting my life on it as against any rival theories" [24].

A series of lectures delivered by Haldane in 1938, published as *The Marxist Philosophy and the Sciences*, became one of the SRS movement's most comprehensive and influential statements on the application of dialectical principles to science, a study called for by Engels in the Preface to his *Anti-Dühring*. "The importance of Professor Haldane's book," wrote a sympathetic commentator, "is indicated by the fact that at last after more than a half-a-century a leading scientist in England has taken up this essential task." And, he continued, Haldane did the job well—"he has not only mastered the essentials of the marxist method, but he has been successful in applying this great weapon so as to make a positive contribution to the marxist interpretation of modern scientific knowledge" [25].

Marxism, asserted Haldane in his introductory exposition of its principles, threw new light on science because it viewed science "as a human activity depending both on contemporary social and economic conditions and also on certain very general laws of human thought" [26]. More modest here in his claims for the value of dialectical materialism in actual scientific research than in his writings for the *Daily Worker* (he wrote a weekly scientific column for the Communist Party newspaper for thirteen years and served as chairman of its editorial board in the 1940s), Haldane applied Marxist principles to mathematics and cosmology, quantum theory and chemistry, biology, psychology, sociology, and the history of science.

The reception to Haldane's book clearly demonstrated that the SRS movement was effective in getting scientists and others to examine Marxism as a legitimate set of beliefs. A reviewer in *Nature*, the English scientific newsweekly, while not conceding that an "explicit philosophy" was absolutely necessary for scientists, thought that Marxism, in its stress on science, was far more stimulating than positivism [27]. Another reviewer thought that Haldane had proven that dialectical materialism was

> an extraordinarily powerful instrument for the interpretation of nature and the control of natural phenomena for human ends . . . . It is surprising to observe how, by deliberately substituting for metaphysical concepts, the constant give-and-take of opposing forces within a field of study, such abstractions as Time and Space, matter, energy, mass, the cell and the organism, body and soul, lose their power to confuse and become the operating elements in an unending dialectical process [28].

And one observer evaluated Haldane's more general purpose. Haldane, he stated,

> does not write for readers in their capacity of consumers willing to fill a leisure hour with scientific gossip but rather as producers into whose labours science has already entered at every point. He creates a synthesis between the theories of scientists and the actions of workers, miners, chemical manufacturers, barmen, who are applied scientists by virtue of economic necessity. . . . Implicit here is the doctrine that the duty of a scientist is not to explain the world but to alter the world, and implicit on every page of [his books] is the author's belief that his duty as an educator is not to help his readers simply to understand the phenomena but to become the *primum mobile* of their evolution [29].

The historian and philosopher of science, Stephen Toulmin, has written that "though it was the poets of the Popular Front era (Auden, Spender, Day Lewis) who took the public eye, the real focus of radical thought in the Britain of the time was among the scientists of Cambridge, and the man at the center of it all was J. D. Bernal" [30].

John Desmond Bernal was the cutting edge of the SRS movement. As an X-ray crystallographer and pioneer in the field of molecular biology, he was universally recognized as a brilliant scientist. No one could neglect his far reaching proposals for an effective organization of science in Britain, his Marxist interpretation of science and society, his view of science as an instrument for socialist revolution. His book, *The Social Function of Science*, which was written in 1939 and climaxed a decade of thinking by the SRS movement, became a symbol of the movement to adherents and opponents alike. His volume, *Science in History* (first edition, 1954), epitomized the Marxist approach to the history of science.

These major works stemmed from Bernal's attempts to create what he called "a science of science"—"a new field of study" to analyze science in its interaction with the social environment [31]. Or, in other words, a more systematic treatment of the areas he, Levy, Haldane and other members of the SRS movement had been exploring for almost ten years. For Bernal, this "science of science" rested on two major inquiries. First, an historical basis for the relation of science to society—in Bernal's words, "an aspect of history which has as yet scarcely been touched" [32]—would have to be established. The work of Farrington, Childe, Crowther, Haldane, and preliminary writings by Bernal in this field had already proven the "revolutionary importance" of the history of science because, in the words of one contemporary commentator [33], it disclosed "the fact that science has always been institutionally tied up with social, economic, and political events, whose irrationalities have retarded and frustrated the possibilities of its unrestricted use for human welfare." Bernal would turn his full attention to this in the 1950s.

In addition to the historical base for a "science of science," hard facts on the status of scientific research and teaching had to be collected, analyzed, and presented in a coherent fashion. Specific questions had to be answered: "How many scientific workers are there? How are they financed? What do they do? How is their work coordinated and directed? How is it linked with the satisfaction of human needs and the removal of human evils?" [34]. Bernal undertook this second task in his monumental work of 1939, *The Social Function of Science.*

The Social Function analyzed both the existing position of science in contemporary capitalist society and the resulting benefits for science and society should the whole scientific enterprise be reorganized—or, in Bernal's words, "What Science Does" and "What Science Could Do." A short list of just some of the chapter titles will give an indication of the enormous scope of the work: "The Existing Organization of Scientific Research in Britain"; "Science in Education"; "The Efficiency of Scientific Research"; "Science and War"; "Scientific Communication"; "The Finance of Science"; "The Strategy of Scientific Advance"; "Science and Social Transformation." The book will have served its purpose, wrote Bernal, "if it succeeds in showing that there is a problem and that on the proper relation of science and society depends the welfare of both" [35].

The book became the pivot for much debate in the 1940s. As it summarized and climaxed a decade of thinking and writing on the social relations of science, it was both a Bible for SRS advocates and the chief target for a newly aroused anti-Marxist, anti-SRS group of scientists.

On the one side was the opinion that "no one [had] ever before provided so comprehensive an analysis of the actual working of science" and its connections with social and economic developments [36]. As a contemporary observer put it, with the appearance of Haldane's *Marxist Philosophy and the Sciences* in 1938 and Bernal's *Social Function* in 1939, "Marxism definitely becomes

a major influence in our thinking on the role of science in society" [37].

Not everyone's thinking, of course. "During the 'thirties,' " John R. Baker wrote to me a few years ago, "I was gradually getting more and more wound up by all the Marxist propaganda until finally I exploded" in a "Counterblast to Bernalism" [38]. Here is how Baker, an Oxford biologist, reacted to *The Social Function of Science:*

> Bernalism is the doctrine of those who profess that the only proper objects of scientific research are to feed people and protect them from the elements, that research workers should be organized in gangs and told what to discover, and that the pursuit of knowledge for its own sake has the same value as the solution of crossword puzzles. . . . What a scientist ought to do is an ethical concern for the judgment of his own conscience. Those to whom one listens with respect when they speak of verifiable matters (e.g., in crystallography) compel attention much less inevitably when they try to lay down the law on moral issues [39].

Michael Polanyi, then a physical chemist at the University of Manchester, did admit that the SRS spokesmen "dazzlingly illuminated. . . the various connections of science with society, the motives for which science is undertaken, the materials which feed it, as well as the effects—good and bad—which result from it." However, they left the "very life of science" in the dark by claiming that "the ideals of a disinterested search for truth and of the cultivation of science for its own sake are unsocial and futile" [40]. And, he asked Bernal, "how can science, if it has to submit to adjustment of its social function at the hands of society, maintain its essence, the spirit of free inquiry?" [41].

Even as Polanyi was writing these words, the social function of science was in fact being adjusted to meet the demands of world war. Bernal became Scientific Advisor to the Chief of Combined Operations and helped the D day landing in 1944 by providing detailed beach maps of Normandy. Haldane was a trusted advisor to the Service Chiefs, working with the Army, Navy, and Air Force on such secret projects as anti-invasion preparations and midget submarines. (This produced the unlikely situation of the chairman of the editorial board of the *Daily Worker* working for the government at the same time his paper was suppressed by the government for hampering the war effort!) World War thus brought many of the SRS group "inside"; Cold War forced them, once more, into "outsider" politics, as they continued to develop ideas first crystallized by that History of Science Congress of 1931.

I have above painted just the barest sketch of the SRS movement. Basing their analysis on Marxism, these scientists were remarkably successful in developing an all-embracing philosophy, history, and sociology of science which also bridged scientific thought and political action. Their effect on contemporaries may have been best put by Hyman Levy: "It has not been easy to be a socialist in academic circles," he wrote in 1945. Scientists "have been slow to appreciate. . . that science has social implications and that certain aspects of science have to be viewed in this context. Most of them never troubled to look at Marxism as seriously as they would examine the most trivial of their scientific problems. . . . The change in outlook in the past ten years amounts almost to a revolution in thought" [42].

But their significance did not, in my opinion, end in 1945. The domestic organizations that they established or to which they gave new direction are the direct ancestors of current groups concerned with the social responsibility of science. On the international scene, they played a major role in founding the World Federation of Scientific Workers, which is still active today, and some of them were involved in setting up the still continuing Pugwash Conferences on Science and World Affairs. And as the magnitude of their intellectual achievement emerges from the clouds of the Cold War, a recent evaluation of Bernal's *Social Function* might be applied to the whole Social Relations of Science Movement: It "forced new thinking on us. It challenged us to see. After twenty-five years we recognize that its challenge has broadened our minds and helped to change the seemingly unchangeable" [43].

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Science and Social Change —

Science appears as a slave to social forces foreign to itself; it appears as an external and uncomprehended force, useful but dangerous, holding a position in society like that of a captive workman at the court of some savage monarch. To a large extent this does represent the position of science in modern capitalist society, but if this were all we should have little to hope for either from science or from society. Fortunately, science has [another] and more important function. It is the chief agent of change in society; at first, unconsciously as technical change, paving the way to economic and social changes, and, latterly, as a more conscious and direct motive for social change itself... The obstacles to the solution of the problem are not any longer mainly physical or biological problems; they are social obstacles.

-- J. D. Bernal, *Social Function of Science*, p. 383.

TABLE I.

(a) Suboptimal form

A self-pitying poet compared
His fortunes to others, despaired
Of the cruelty of fate
'Til he thought on his mate
And then like a skylark he fared.

(b) Optimal

When in disgrace with fortune and men's eyes
I all alone beweep my outcast state
And trouble deaf heavens with my bootless cries
And look upon myself and curse my fate,
Wishing me like to one more rich in hope,
Featured like him, like him with friends possessed,
Desiring this man's art and that man's scope,
With what I most enjoy contented least;
Yet in these thoughts myself almost despising
Haply I think on thee and then my state
Like to the lark at break of day arising
From sullen earth, sings hymns at heaven's gate;
For thy sweet love remembered such wealth brings
That then I scorn to change my state with kings.

(c) Supra-optimal

When in disgrace with fortune and men's eyes
I hear folk snickering behind my back
And trouble deaf heaven with my bootless cries
Of "Woe is me" and "fuck it" and "alack",
I all alone beweep my outcast state
And, in excess, in company as well,
And look upon myself and curse my fate
And scorn my looks, my touch, my sound, my smell,
Wishing me like to one more rich in hope,
In ships, in shares, in titles, stocks, and bonds,
Desiring this man's art and that man's scope
Of this man's lakes or even that man's ponds,
Featured like them, like them with friends possessed,
At least with contacts, and with fine abodes,
With what I most enjoy contented least:
An ear for sonnets and a flair for odes.
Yet in these thoughts myself almost despising
For coveting alone what I have not,
Like to the owl at fall of night arising
To share the pewter and the pity pot,
Haply I think on thee and then my state
Like holy Mary's Bodily Assumption
From sullen earth sings hymns at heaven's gate,
My hopes return, my humor and my gumption,
For thy sweet love remembered such wealth brings
That banish goblins, doubts and dismal scenes
So then I scorn to change my state with kings,
With bankers, popes, or academic deans.

A Satyrical Comment on the Reductionist Theory of Edward O. Wilson & Co.

AN EVOLUTIONARY INTERPRETATION OF THE ENGLISH SONNET

Isadore Nabi

The First Annual Piltdown Lecture on Man and Nature

A Rodin study
Atkins Museum
Kansas City

The fundamental proposition of sociobiology (the new synthesis) is that human cultural behavior can be explained and understood as the outcome of natural selection acting on that behavior in such a way as to maximize the inclusive fitness of the actor. This theory can, in principle, account for both the invariants of the human condition and those traits which vary in space and time and can be applied to several levels of natural organization including the individual, the nuclear family, kin group, joint stock company, nation, or class.

The present paper examines the English, 14-line sonnet as an adaptive trait.

The adaptive significance of cultural behavior is two-fold: it mediates the relation of man to nature (the competition for food or struggle against predators) and the relations of men to each other (the struggle for access to females). Therefore, the first question is, which of these roles is the major adaptive significance of the sonnet?

A textual analysis shows possible significance for either role. References to nature abound, either by way of sharpening the sensory focus on potential resources ("hark, hark, the lark!") or by atuning man's activity cycle to the deep rhythms of the seasons ("shall I compare thee to a summer's day?"). Note that this is expressed as a question. Then follows further description of summers' days so that at the end the hearer may be better able to cultivate the corn at the appropriate time.

However, on the whole the 14-line English sonnet seems to be more related to the winning of mates than the struggle for food, and should be seen as part of courtship behavior. Our hypothesis then, is that the English sonnet is a sex organ, and that like more corporeal sex organs, it has an optimal size which will be selected for.

In order to serve its purpose as mediating early coupling, the sonnet must be long enough to arouse the interest of the receptive female.

Clearly the couplet, quatrain, or limerick are too brief to induce more than a flicker of interest. On the other hand, if the sonnet were too long it would interfere with the later stages of courtship, the open-ended heroic epic for example would dilute any passion into "words, words, words!", or the lady's husband may return.

Therefore, there is some intermediate optimum which balances the needs of arousal and consummation, courtship and safety, passion and prudence, allowing man to reproduce himself with minimum risk and maximum issue.

That this optimum is approximately 14 lines is shown by the following:

(1) Fourteen is a subharmonic of the 28-day menstrual cycle, thus evoking deep (hypothalamic-limbic) instinctual rhythms.

(2) Sonnet-writing peoples have been among the most successful in the world whether measured in terms of population growth, geographic spread, spawning of new populations (cladistic evolution), relative share in world petroleum consumption, military potential, foreign investment, or other measures of all-inclusive fitness.

(3) In Table I, we compare the 14-line English sonnet to longer and shorter versions of the same theme. This procedure, modeled after the familiar techniques of perturbation analysis, demonstrates the patent superiority of the 14-liner over small and medium deviations from it.

(4) There is no evidence that Neanderthalers wrote sonnets (their art emphasized food-getting). They are extinct.

(5) The sonnet has an insignificant role in gay literature.

Discussion

The demonstration that the 14-line sonnet was selected as the optimum early-courtship behavior (at least in a cold climate) is consistent with the role of sonic communication in bird courtship as well, and may be important in the pairing of dolphins and of killer whales.

But a gene for sonnet writing in the male would lack adaptive value without a corresponding receptor site in the female. The sonnet receptivity lows (SRL) may prove to be linked with other genes in the Gullibility and Role regions of the X-chromosome, such as the Emotionality locus (EL), Intuitiveness locus (IL), Submissiveness locus (SL), etc. We note that there seems to be a one-to-one correspondence between male and female behaviors reminiscent of the gene-for gene equivalences of rust resistant loci in wheat and anti-resistance loci in wheat rust. On the other hand, in humans we may be dealing with the same genes in both sexes, which express themselves differently depending on genetically determined sex.

The author is of course aware of the importance of culture and recognizes, for example, that the Italian sonnet is frequently written in Italian and often ignores larks. Therefore, my own conservative estimate is that approximately 7% of the English sonnet is genetically determined, and that this 7% must include the size-regulating 14th line.

Summary

It is shown that the Fourteen Line English Sonnet (FLES) has evolved from birdsongs as an optimal early courtship behavior in Man.

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Editors philosophical remarks. This gentle spoof by a pseudonymous Nabi reflects quite well the anthropomorphic and mechanistic concept of the gene in sociobiology—popularized by Dawkins as *The Selfish Gene*, and implemented in a rash of papers in scientific journals demonstrating how the male (bluebird, garter snake, or so forth) protects *his* "gene investment". For this most recent formulation of genetic determinism, Edward O. Wilson of Harvard has received wide acclaim from the competitive social system that he reflects; Jimmy Carter gave him the National Medal of Science in 1977.

Wilson's exhaustive treatise *Sociobiology: The New Synthesis* [1975] starts right off [p.4] by explaining "The Morality of the Gene" in terms that relegate cortical processes to a secondary role in social behavior:

> The hypothalamic-limbic complex of a highly social species, such as man, "knows," or more precisely it has been programmed to perform as if it knows, that its underlying genes will be proliferated maximally only if it orchestrates behavioral responses that bring into play an efficient mixture of personal survival, reproduction, and altruism.

Defining sociobiology as "the systematic study of the biological basis of *all* social behavior" [emphasis added], Wilson makes it clear that genetic influence must take precedence over historical development as the key to understanding "all" social processes and class-divided social structures:

> Sociology *sensu stricto,* the study of human societies at all levels of complexity, still stands apart from sociobiology, because of its largely structuralist approach and nongenetic approach. It attempts to explain human behavior primarily by empirical description of the outermost phenotypes and by unaided intuition, without reference to evolutionary explanations in the true genetic sense. [ibid.]

Since human society regrettably still defies reduction to an equation, Wilson formulates his present goal as follows: "When the same parameters and quantitative theory are used to analyze both termite colonies and troops of macaque monkeys, we will have a unified science of sociobiology." But even in this seeming modest goal, he would deny the development of qualitative differences in the laws governing the potential and actual social organizations for such widely divergent organisms. Because of the mechanistic nature of his proposed model, Wilson can find philosophical support from otherwise strange bedfellows such as Noam Chomsky, Herbert Marcuse and B.F. Skinner. (He does not mention either Marx or Engels.) And, predictably, his mechanistic materialism leads to some blatantly idealist formulations, such as a genetic basis for religion too.

Now, this criticism of Wilson's philosophical approach does not imply rejection of all his work. Who would deny that the biology of the individual organism plays a dialectical role in collective social behavior? This was discussed by Pyotr Fedoseyev in *Social Sciences* (Moscow) 9 (3): 20-43, 1978 (excerpted in *Science and Nature* No. 2). For more extended discussions, Ashley Montagu has recommended:

Marshall Sahlins, *The Use and Abuse of Biology: An Anthropological Critique of Sociobiology*. Univ of Michigan Press 1976.

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On Revolution in Epistemology

In effect, a "dialectization" of science is taking place, resulting in an expansion of the historical and cultural context that regards cognition as a reflection of being and a socially determined historical process. In recent years, Western philosophy has also begun to accept the principle of combining the epistemological and socio-cultural approaches for the construction of dynamical historical models of scientific knowledge. Up to the mid-1960s this field was dominated by neopositivism with its basic anti-historism and narrow empiricism, but these positions proved inadequate for elaborating an effective integrated programme in keeping with the needs and spirit of modern science. Hence, post-positivist theories such as "critical rationalism" (K. Popper, H. Albert) and the "historical trend" in philosophy of science (T. Kuhn, S. Toulmin, P. Feyerabend) aimed to formulate a logical-methodological model of scientific knowledge that would more closely approximate the laws of scientific development. But this can hardly be regarded as a kind of "Copernican" revolution.

The principles of constructing dynamic models of scientific knowledge have been long and fruitfully employed in the Marxist methodology of science. One of the fundamental results of Lenin's analysis of the revolution in natural science was the conclusion that progress in science is subject to dialectical laws.

The growth of scientific knowledge is accompanied, not only by an expansion of the cognitive content of theories but also by an enrichment of the logical means of cognition, changes in scientific norms and standards—or thought paradigms, to use a modern methodological term. The revolutionary transformation of the scientific picture of the world called for a radical change in the very mentality of scientists, a transition from the metaphysical to a higher and more consistent form of materialism: *dialectical* materialism!

-- *V. Kurayev, Materialist Dialectics and the Growth of Knowledge.* Social Sciences *(1) 1980 (abridged excerpt).*

Ideology of/in the natural sciences, Hilary and Steven Rose, editors (Schenkman, Cambridge, Mass. 1980)

Reviewed by Shaun Lovejoy, McGill University, and Hyman R. Cohen, Dialectics Workshop

In this collection of 16 essays by as many authors, various aspects of the relationship between capitalism and science are investigated. One cannot but be impressed with the scope of the book. Discussions range over ideology in physics, science in China, women in science, Black liberation and science, Lysenkoism, ecology, women's liberation, I.Q. testing, and more. Some of the essays are of high quality and significant interest. Even where disappointing, the determination and energy with which a subject is attacked often offsets to some extent what is lacking in hard research and analysis. As a whole, the book is provocative.

Deserving particular attention is Joseph Needham's scholarly and fascinating account of the historical development of science in China. He addresses the question of why China was so far ahead of Europe in science until about the 16th century, based on his immense life-work, *Science and Civilization in China.* His basic thesis is that Chinese culture provided a fundamentally different environment for science because the dominant ideologies included no supernatural force outside of nature to dominate man, thus no divine source of knowledge about nature to obstruct scientific investigation as in Medieval Europe.

Pursuing this argument to the period of the Enlightenment, Needham says that in China, with no divine moral authority, there was also no opposing mechanistic tendency to absolutize the natural sciences, i.e., no "scientistic" belief that moral, ethical and social values can be derived from the natural sciences. Thus, he sees "scientism" as a peculiarly Western phenomenon and today's "counter-culture"—at least in its anti-scientific, anti-technological aspects—thereby a humanistic reaction to the alienation of a "scientistic" society.

Though Needham documents this argumant well, he seems to realize that he treads on dangerous ground; it is a short step from "scientism" to Brzezinski's "technotronic" characterization of a society by non-social determinants. Needham carefully skirts around this particular trap but then quotes approvingly the Mao dictum to "put politics in command", seeing it as an affirmation of the Chinese tradition of placing the moral and human above all else. In China, unfortunately, this dictum was interpreted one-sidedly, creating the illusion that putting political ideology "in command" could override the laws of development of political economy—whereas in the west we have to combat the opposite illusion that social processes can be determined completely by non-social (non-political) means.

Whether or not one subscribes to Needham's conclusions about contemporary society, this work is of great importance because it points to a completely different and remarkably successful route to scientific knowledge. There is no doubt that his contrast of Chinese and western science helps illuminate the social roots of scientific development.

Also of special interest is the essay on political ecology by Hans Magnus Enzensberger who criticizes the left for its relative indifference to ecological issues, noting the comparatively few political links between the two movements and the left's failure to go beyond a criticism of the middle-class character of the ecological movement. Asking for a serious look at the often valid ecological concerns in the Marxist perspective of the man/nature dialectical interaction, Enzensberger argues that the "ecological crisis" gives an urgent new dimension (and new political possibilities) to the century-old choice between socialism and barbarism. He concludes: "Socialism, which was once a promise of liberation, has become a question of survival. If the ecological equilibrium is broken, then the rule of freedom will be further off than ever." One may feel that ecological disaster is further away than he implies, yet agree that it is high time for the left to examine these questions more seriously and to cooperate politically with the ecologists wherever possible.

Another important contribution is the well-researched critique of "radical feminism" by Hilary Rose and Jalna Hanmer on "Women's Liberation: Reproduction and the Technological Fix". The authors identify themselves with the Marxist feminist tendency, now searching for a program in which the *Marxist* and the *feminist* will be truly united. Indeed, the serious theoretical and political errors of the radical feminists may stem in part from insufficient depth in Marxist critiques of feminism. The focus of the present critique is the glaringly inadequate idea of a "technological fix" as espoused by many radical feminists, particularly Shulamith Firestone in *The Dialectic of Sex*: the belief that women's oppression is primarily the result of biology, and thus that the path to liberation is through biological equality, to be achieved ultimately via test-tube babies. Documenting a remarkable affinity of this idea with the views of frankly reactionary social engineers, such as Etzioni, and the "friendly fascist" Shockley, the authors achieve a powerful indictment of the "technological fix" theory.

Though the esseay is excellent at the level of exposé, it is marred by weaknesses concerning alternative approaches. Exhibiting an all-too-familiar New Left blind spot, the authors make the incredible assertion that Mao was the first major Marxist leader to take seriously the question of women's liberation, and that China is the only major socialist country in which women have played (and by implication, play) a major role. Since little by way of argument or fact is given to substantiate these claims, they will not be dealt with here. It is sufficient to note that only three years after this feminist praise of China, many social-engineering practices they rightly criticized have been adopted there; examples are the loss of full pension for couples with *any* children, loss of monthly "bonus" for

those with more than one child, reduction of salary by 10% for those with more than two, etc. These measures bear an uncanny resemblance to those foisted upon the people of India in the name of curbing "overpopulation".

At a more theoretical level is an ambitious essay by Ciccotti *et al.*, "The production of science in advanced capitalist society" outlining a model for the development of science based entirely upon external social influences. This model seems misguided, since it constitutes denial of the relative autonomy of science. There is cogency, however, in their more limited thesis that information has become a commodity. They argue that, under conditions of generalized commodity production, information becomes a commodity used to intensify the exploitation of labor. They point to an increasing rate of production of information in the particular form of patents for processes, techniques, designs, etc. An interesting point in their argument is that the concept of "neutrality of science" becomes a specific form of commodity fetishism, screening the social basis for the production of scientific information as a commodity.

The real problem with this sort of social determinism emerges, however, when the authors, extrapolating from the concept of information as a commodity generated by applied science, apply the same analysis to "pure science". Their discussion centers around funding for science that gives the capitalists direction and control of science, but they ultimately leave out the essential ingredient: reality. Indeed, we find them quoting with approval: "there no longer exist criteria of truth in a strict sense... theoretical physics can no longer explain anything..." With the concept of truth thus evaporating, so also vanishes science as producer of "universal knowledge", the very root of Marx's belief in the ultimately progressive role of science. As elsewhere in the volume, this denial of scientific truth is intimately linked with the idea of technology as an autonomous oppressive force, and with the denigration of the "dialectics of nature" on which Engels and Lenin insisted, i.e., the indissoluble unity of the human and the natural. Although the essay contains this fundamental flaw, the concept of information as commodity deserves further investigation. Can it be developed along classical Marxist lines as the authors claim or is it just an elaborate analogy, another hypothesis to be discarded?

Other interesting essays are by Lewontin and Levins, a convincing account of Lysenkoism, and by Steven Rose on the I.Q. controversy.

The remaining essays will not be described individually; instead we will attempt to deal generally with their philosophical and political shortcomings, some of which have been noted above. The theoretical problems encountered here stem in the main from an incorrect treatment of the concepts of ideology and science. While some ideology, defined narrowly as "false consciousness", can only be opposed to science since the latter process seeks always to find "true consciousness", the actual interpenetration of truth and falsehood in scientific consciousness is far more subtle than assumed by many of the authors. Similarly, they often fail to differentiate clearly between social science, where class ideology is usually rampant, and the natural sciences, where class ideology is less likely to appear. Though rightly rejecting the notion of "neutrality" of science, they tend to produce evidence of the absolute partiality implied in formulations like "science as ideology". In spite of an abundance of references to *ideology in science,* virtually all discussion and evidence concerns *science in ideology.* For example, in an account of the I.Q. controversy, the racist use of I.Q. theory and genetic theory are clearly ideological uses of educational testing and the scientific theory of inheritance respectively. It is not made clear how much the reverse process of actual influence on scientific concepts by racist ideology has actually occurred. Indeed, such a study would require meticulous investigation into the historical development of a science, a much more difficult task than studying, at the level of sociology, the ideological uses to which science is put.

The frequent confusion of *ideology in science* with *science in ideology* has severe consequences because it blurs the crucial (albeit not absolute) distinction between science and the uses to which science is put. Thus, deleterious effects of scientific management, automation and fragmentation of skills under capitalism become attributes of science and technology *per se*—they "could not but be oppressive"— regardless of the social system. Symptomatic of this denial of the importance of social factors are an ill-informed negative assessment of the advanced socialist countries and an equally ill-informed laudatory appraisal of those suffering extreme underdevelopment, particularly China where social relations are made absolute. Such a one-sided evaluation of the Chinese situation was not philosophically defensible even in 1976 when the book first appeared in England. Similarly misplaced is an uncritical acceptance of syndicalism as an important modus operandi in advanced socialist countries.

At the root of the tendency to identify science with ideology is a rejection of the thinking of Engels and Lenin concerning the relation of man and nature, which is put in opposition to that of Marx. In particular, dialectics is seen to originate with social mankind (there is only historical materialism). The continuity of historical development from the inorganic world to the living world and then to humanity and society is thus broken, with nature regarded only as an external object and humankind as an independent subject. From here, it is a short step to the denial of necessity, particularly necessity in the form of economic laws governing social development, and thence to enthusiasm for a "cultural revolution" which proclaimed an end to these laws. The historical consequences of this denial needs little comment.

Despite some emphasis here on weaknesses of the book, there is no denying the outstanding merit of having addressed the problems in the first place. Indeed, Marxists in the west have given all too little thought to the relationship of science to society and to ideology. The necessity of rapidly increasing our understanding of these problems is crucial at this moment when scientists are increasingly involved, not only as contributors to, but also as victims of the morbidly stagnating capitalism of the 1980s.

Editor's note: Let me add a plea here for more dialogue on the left concerning the questions raised in the above review. Since this journal is associated with the epistemology (and political economy) developed by Marx, Engels and Lenin, we recognize the need for more work on the nature of scientific knowledge and the sociological aspects of this problem. Hence, our pages are open for discussion of these matters from a dialectical materialist view.

Steven Rose sent me his summary of what was evidently a very stimulating meeting on *The dialectics of biology and society in the production of mind* (Bressanone, Italy, 26-30 March 1980) at which participants included some of the authors reviewed above. Emphasis of the discussions was on the struggle against reductionism and, judging from summarized give-and-take, the critical and self-critical comments concerning mechanistic tendencies of the authors reflected some healthy conceptual development.

Clearly, people may take different sides on epistemological problems and yet share the same genuine concerns on urgent social problems, including problems in sociology of science. So, while we engage in philosophical dialogue, let us also join hands on practical issues such as saving the world from a nuclear holocaust. □

On Ideology in Science

When and under what circumstances we reached, in our knowledge of the essential nature of things, the discovery of alizarin in coal 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. In a word, every ideology is historically conditional, but it is unconditionally true that to every scientific ideology (as distinct, for instance, from religious ideology) there corresponds an objective truth, absolute nature. You will say that this distinction between relative and absolute truth is indefinite. And I shall reply: It is sufficiently "indefinite" to prevent science from becoming a dogma in the bad sense of the term, from becoming something dead, frozen, ossified...

-- V. I. Lenin, *Materialism and Empirio-Criticism.* Moscow 1962, p. 136.

In a class-divided society, therefore, closely interwoven with the "absolutely objective knowledge" inherited from past societies or newly won by that society, in any actual science there are theories, modes of approach, views, which arise directly or indirectly from the productive relations. Such theories and views, arising from the class relations, in the last resort express the interests and conflicts of classes in that particular stage of society, and may be progressive or reactionary, may help society forward or hold it back, may be to one degree or another one-sided, limited, or false...

But this does not mean that the accumulation of "absolutely objective knowledge" is impossible in a class society. On the contrary, such knowledge is linked with and tested by practice in all societies; without it, no society could live and develop. When we speak of "bourgeois science" we do not belittle the immense scientific achievements of bourgeois society which in fact are in large measure the starting-point for "socialist science".

-- Emile Burns, *Masses and Mainstream,* Sept. 1953, pp. 46-53.

BIBLIOGRAPHIC NOTES FOR NATURAL SCIENTISTS

Annotation is by the editor except as noted.

**Asterisk designates item from a socialist country available through Imported Publications Inc., 320 W. Ohio Street, Chicago, Ill. 60610.*

SCIENCE AND PHILOSOPHY

Richard Levins and Richard Lewontin 1980 Dialectics and Reductionism in Ecology. *Synthese* 43: 47-93.

In this polemic on conceptual issues of ecology, the authors develop a Marxist approach to some "common confusions" of biology in a manner that makes the paper of interest to all scientists

To clarify the difference between reductionism and materialism, they consider an ensemble that includes species and environment, characterized as an object with dynamical laws that can only be expressed in a space of appropriate dimensionality reflecting the dialectical whole. In this object, interactive causal relations assume a community character that is not apparent when changes of a single element are considered alone. Intthis view, large-scale computer models of systems ecology are not meaningfully holistic since no new objects arise at the community level. Hence, they conclude, the properties of the community and of its constituent populations must be linked by many-to-one and one-to-many couplings that depend on the concrete circumstances of their historical development.

To clarify the nature of abstraction, they consider the practical example of an ecological community treated as an isolate. Though all species of the biosphere do interact, they point out that in practice the matrix of interaction coefficients is essentially decomposable into a large number of submatrices separated by zeroes, and that the problem for ecologists is to find the boundaries of such submatrices rather than to worry about the infinitesimally small actual numbers of the coefficient values outside these boundaries. Thus they take practical epistemological consequences as the distinction between scientific abstraction and metaphysical idealization.

To clarify confusion on stochasticity and statistics, an example is cited in which stochastic modeling was consistent with the variable outcome of experiments but seemed untestable whereas an alternative model that would lead directly to experiment and measurement had been rejected. "It may be true," they comment, "that notions of cause-and-effect are inapplicable at the level of the spontaneous disintegration of a radioactive nucleus, but there is no reason to make uncertainty an ontological property of all phenomena." An illuminating discussion of statistical methods is based on their philosophical view: "Some of the greatest problems of scientific explanation come from concepts and practices that lie at the heart of modern statistics which, in many ways, is the embodiment of idealism, at least as practiced by natural and social scientists."

Regina Karpinskaya 1970 Philosophical Significance of Modern Biology. *Social Sciences* (Moscow) 10 (2): 119-134.*

The concept of invariance, associated with molecular biology and genetics, is seen here as bringing together the science of the animate and the inanimate, though exaggeration of the concept (Dawkins, Monod) leads to anti-dialectical postulates on the immutability of genetic invariants that contradict evolutionary theory.
The author, a senior researcher, Institute of Philosophy, USSR Academy of Sciences, addresses the larger question of how biology, which can never renounce the ideas of evolution and its modes of development, fits into a scientific world picture where physics, holding first place, will not abandon its established principles of cognition which so far have not had to enlist historical time.

Complicating her problem further is the fact that biology includes man simultaneously as subject and object of investigation.

Keytto Karpinskaya's attack on this problem is recognition that, while there is no direct link between biological evolutionism and the physical picture of the world, an intermediate link is provided by the study of chemical and biochemical evolution. She points out, for example, that genetic engineering is not only a new method of understanding biological systems but also a new linking of human activity with the objective process of the evolution of matter.

Final resolution comes through recognizing that the various sciences, including biology and chemistry, participate in the process of cognizing objective reality quite apart from the "scientific world picture" which itself is really a philosophical construct that undergoes continual development as a function of its changing cultural environment. In this process, physics is found to have the determining role in cognition of "the systems-structural characteristics of matter." However, some more general definition of development is needed, based on evolutionary concepts from the other sciences; biology itself must also develop further through its links with the humanitarian sciences of human ecology, human genetics and the study of the evolution of the biosphere. The inclusion of such matter in the physical picture of the world, predicts the author, will bring further development, from its purely natural scientific character, into "an ideal image of the world as a whole, which embraces natural scientific, humanitarian, and philosophical knowledge."

P. N. Fedoseyev, *et al.* 1978 *Lenin and Modern Natural Science.* Progress, Moscow (revised, translated from 1968 Russian edition). $5.75.*

Sixteen thoughtful essays by leading Marxists provide valuable insights on philosophical, methodological and historical problems in the physical and biological sciences. Some highlights are:

- A hard-bitten materialist critique of those who introduce mystification into cosmology (astronomers Ambartsumyan and Kazyutinsky).
- The complexity and contradictoriness of general relativity revealed clearly without mathematics (A. D. Alexandrov).
- Lenin's views on the implementation of scientific enterprises in the capitalist and socialist worlds (J. D. Bernal).
- Purpose as a historically-acquired property of evey living species in its adaptive evolution (N. P. Dubinin).
- Penetrating comments on the problems of elementariness and structure in particle physics (Barashenkov & Blokhintsev; Shoichi Sakata).
- Key questions concerning the subjective and the objective in dialectical materialist epistemology (P. V. Kopnin & P. S. Dyshlevy).
- Able expositions of the prevailing statistical interpretation of quantum mechanics (V. A. Fok; M. E. Omelyanovsky).
- History of the natural sciences as the source for the creative elaboration of Marxist dialectics (B. M. Kedrov).
- Other papers cover the earth sciences (Y. K. Fyodorov) and cybernetics (A. I. Berg and B. V. Biryukov).

Lee Coe 1969 The Nature of Time *Amer Jour Phys* 37: 810-15; 39: 117-19.

A materialist approach to removing the mystery from the concept of time. The theoretical conclusion that time is a general property of matter is buttressed by descriptive material on the way that time is actually treated in practical scientific work. One could wish that the discussion were more dialectical and that it dealt with questions of non-cyclical material change as well as relativity theory. On the he latter point, however, the author says (private communication) that he couldn't get published if he spoke his mind on the clock paradox. Reprints and copies of additional correspondence with other scientists are available from author: 840 Delaware St., Berkeley CA 94710.

V. Gott 1977 *This Amazing, Amazing, Amazing but Knowable Universe.* Progress, Moscow.*

Here is a stimulating popular introduction to the objective contradictions of nature, by a physicist who studied under the great Lev Landau. Examples of his lively conceptual discussions are:

1) Motion is treated as a dialectical unity of opposites–change and rest–resolving the contradiction by viewing rest as a specific case of motion, as relative rest. We can speak of rest only when we mentally sever a body's links with other bodies and view it in isolation. However, no single body can be found in a state of rest that is not at the same time a part of some moving system [pp 51-52].

2) In the process of change or transformation, a material object possesses the properties of both being and non-being because the process involves both conception and destruction. (Note that the concept "annihilation of matter," found in some works on physics, is inaccurate because it implies the transformation of matter into nothing, the destruction of matter. The term "annihilation" is correctly applied in physics to the process in which particles and anti-particles are transformed into radiation: one form of matter, substance, turns into another, field, but there is no destruction of matter.) It is easy to understand that the destruction of a given concrete thing can be viewed as its transition to non-being ("nothing") while its emergence can be viewed as the transition to being ("something") [pp 70-71]. One may say of virtual particles that their objective being is characterized by a unity of conception and "annihilation" [p. 209].

3) Gott does not engage in extensive polemics with those who, like George Lukacs, deny that nature is dialectical but he knows the difference between contradictions in objective reality and in thought [p. 205]. [Saul Birnbaum, Bronx Community College.]

SCIENCE AND PEACE

W. K. H. Panofsky 1979 *Arms Control and SALT II.* University of Washington.

Physicist Panofsky gives us a perceptive exposition of the urgent need for control of nuclear arms, discussing the problems of technology, military doctrine and political processes. In the ongoing struggle for SALT II as the necessary basis for negotiating actual reduction of nuclear weapons, this slim volume emphasizes the contradiction between the reality of nuclear destructiveness and the way these weapons are perceived by those opposing limitation agreements.

W. K. H. Panofsky and Edward Teller 1979 Debate on SALT II. *Physics Today* June, pp. 32-38.

This debate is useful if only to prove again that the survival of mankind cannot be achieved on the basis of agreement within the community of natural scientists. Panofsky's position, since proved to be alarmingly correct: while SALT agreements have yet to halt the arms race, "defeat of SALT II would be a major setback towards attaining more incisive arms control in the future." Teller relies heavily on the authority of Henry Kissinger in arguing for more weapons and against signing or ratifying SALT II but makes his own position clear: "To avoid a nuclear war is truly the interest of everyone. However, to speak of annihilating humanity is an exaggeration."

The 1979 SIPRI Yearbook. London. (Distributed in USA by Crane, Rusak & Co.)

The Stockholm International Peace Research Institute 1979 Yearbook provides an ominous look into the technical aspects of the arms race. This staggering com-

Man of Science. Signature interpreted as M. Kranz, 1839. (Collection of Edgar William and Bernice Chrysler Garbisch.)

A Scientist Led First World Peace Congress

Frédéric Joliot-Curie, the president of the [1949] Congress, was one of the first scientists to explain the tremendous power of atomic energy as well as the opportunities of using it for beneficial or evil purposes. What he said paved the way for the Stockholm Appeal of March, 1950. Everybody realized that that unknown force, atomic energy, can lead to the self-destruction of humankind or to unparalleled technological advance.

This man, Joliot-Curie, united two things in himself that are united in sound in the German language: Wissen and Gewissen, knowledge and conscience. The two things together constitute an irresistible force. The first World Peace Congress was penetrated by this force and radiated it.

-- Anna Seghers, German anti-fascist writer (*Daily World* 13 Sept 1979).

pendium of modern arms also gives a sober (and sobering) case for disarmament. It is argued that, with the revolutionary advances in land and sea-based ballistic missiles as well as in anti-submarine warfare, the U. S. is now on the threshold of a first-strike capability: "there are serious grounds to fear that the concept of mutual assured destruction, with all its faults, will be abandoned in favour of a war-fighting and war-winning strategy..." The implications for a decaying capitalism in the 80s may be profound. [Shaun Lovejoy, McGill.]

Einstein and Peace 1979 A special issue of *Bulletin of the Atomic Scientists.* Vol. 35, no. 3 (March).

A useful collection of quotations by and reminiscences of Albert Einstein, tracing his development from pacifist to world-state advocate and staunch opponent of the Cold Warriors. Of special note is the story of wartime heroism by Frederic Joliot-Curie who used his academic position to divert Nazi attention away from atomic fission while simultaneously helping lead the underground French Resistance, a role that culminated in his manufacture of explosives after the Normandy landings [and participation in the liberation of Paris by preparing Molotov cocktails]. Though Soviet physicist M. A. Markov quotes Einstein briefly on the class basis of German and Japanese militarism, the economic origins of modern war are largely neglected in the papers of this issue, as they seem to have been in the actual peace efforts of Einstein and other scientists.

J. D. Bernal 1971 War and Science. *Science in History.* MIT Press. Vol 3, Section 10.10.

"Unfortunately in this century," says the late great physicist and historian, "when international co-operation in science has been most needed and most useful, it has also been most hindered. Wars and revolutions, and the threat of still more to come, have been most effective in holding up the advance and diverting the uses of science." After dealing with the role of science in developing the weapons for "inhuman warfare," he deftly portrays the effect of war and militarism on science itself in a time when "government laboratories have come to rival universities for post-graduate work, and university physics departments have become annexes to government contract schemes inside them," with the consequent role of "loyalty oaths." Elsewhere in the four volumes of Bernal's work, problems of war and science are similarly given a Marxist orientation with respect to class interests and social structures.

Leopold Infeld 1948 *Whom the Gods Love: The Story of Evariste Galois.* New York. (Reprinted 1978, Natl. Council of Teachers of Mathematics.)

Seldom has one human life combined so much drama and tragedy in so few years? The youthful mathematical genius in his unbelievable struggle against a self-serving academic establishment is here a unity with the courageous firebrand and his magnificent Republicanism, challenging the entire oppressive regime of Louis Phillipe. This fictionalized biography fills in the factual gaps to provide rounded interpretation of a heroic life that has great meaning for today. The book is infused with the democratic consciousness of an outstanding physicist-author (one time collaborator with Einstein) who returned, after World War II, to the University of Krakow in his native Poland. Highly recommended for students and all who are youthful in spirit.

Izaak Wirszup 1979 *Preview Report to the National Science Foundation on Soviet Education and Manpower Training.* Available from author, Univ of Chicago, Dept of Mathematics, 5734 University Avenue, Chicago Ill 60637.

This comparative study of Soviet and U.S. pre-college education documents what the Soviets call an "educational revolution," effected since the Stalin era and

J. D. Bernal on War Against Science

The greatest and most dangerous distortion of science in Britain and the United States is that from preparation for war. This has three bad effects on science which reinforce each other. In the first place, the objective of destruction is increasingly that of blind slaughter without even military excuse. This is foreign to the whole tradition of science and inevitably demoralizes the whole body of scientific workers who, coming to accept this as a matter of course, tend to lose all sense of social responsibility and moral value in science. Further it gives apparent justification to the non-scientific public to associate science with war in its most horrible aspects, lending additional support to the popular tendency of dislike for and suspicion of science and scientists.

Secondly, though purely military research has of its very nature to be carried out in secrecy, this secrecy is extremely difficult to limit. Large areas of new science, known vaguely to exist, are kept out of the common pool. The secrecy thus destroys the free communication of scientists nationally and, even more, internationally. Finally, the concentration on military science drains off men and, even more, material support from those branches of science which increase man's knowledge and control over his environment and enable him to deal with the urgent needs of providing food, increased industrial productivity and health care. -- *Science for Peace and Socialism,* Bernal and Cornforth. London 1949, pp 33-34, abridged.

culminating in the 1975 introduction of compulsory 10-year schooling (with 97.7% graduation rate). Moreover, the compulsory curriculum for these 10 years of schooling includes 10 years of arithmetic and algebra, 10 years of geometry, 2 years of calculus, 15.5 years of natural sciences, 5 years of geography, and 13 years of workshop training and mechanical drawing.

Some problems are reported. Sharp public discussion is now under way over the heavy burden on students and teachers. And the Academicians are said to be split two ways on Kolmogorov's modern approach and rigor.

Prof. Wirszup seemed to give an objective and dispassionate report until his conclusion: *"It is my considered opinion that the recent Soviet educational mobilization, although not as spectacular as the launching of the first Sputnik, poses a formidable challenge to the national security of the United States, one that is far more threatening than any in the past and one that will be much more difficult to meet."* [Emphasis in original.]

One may suppose that this is just standard grantsmanship: Give the congressmen chills over Soviet children doing their sums correctly and you get your budget upped (Prof. Wirszup is director of *two* NSF programs). But will this Cold War appeal help improve the science and math education here in the U.S. or merely contribute to the drive toward sending our young people into basic training?

BOOKS RECEIVED

Erwin Chargaff 1978 *Heraclitean Fire: Sketches from a Life Before Nature.* Rockefeller University Press.

Freeman Dyson 1979 *Disturbing the Universe.* Harper & Row.

Ludwik Fleck 1979 *Genesis and Development of a Scientific Fact.* University of Chicago Press.

Ruth Hubbard and Marian Lowe, editors 1979 *Genes and Gender II: Pitfalls in Research on Sex and Gender.* Gordian Press (85 Tompkins St., Staten Island, NY 10304: $6.95).

Revolutionary World vol 23/25 (1977). The Struggle for a Dialectical Materialism, special triple issue.

— vol 27 (1978). Special issue of the German Democratic Republic.

— vol 28 (1978). Special Soviet issue, edited by Bernard Bykhovsky and translated by Philip D. Moran.

Hubert C. Kennedy 1980 *Peano: Life and Works of Giuseppe Peano.* D. Reidel. Paper $14.95, cloth $34.00.

A Beginner's Bookshelf on Marxism in Natural Science

Reader in Marxist Philosophy. Howard Selsam and Harry Martel, editors. International, New York 1963. Paper $3.50, cloth $7.50.

Dialectical Materialism. Maurice Cornforth. International, New York 1972. Three volumes, paper $5.00

Marxist-Leninist Philosophy. Alexander Petrovich Sheptulin. Progress (Moscow) 1978.*

Materialism and Empirio-Criticism. Vladimir Ilyich Lenin. International, New York 1970. Paper $2.95, cloth $7.50.

Dialectics of Nature. Frederick Engels. International, New York 1940. Paper $2.85, cloth $7.50.

JOURNAL WITH A MISSION

Most scientists would agree that science is inherently materialist. Whether experimentalist, theoretician, or both, the scientist at work must inevitably employ materialist principles (such as causality), whether conscious of this or not. It is somewhat similar with the dialectical mode of thought. Science in general deals with processes rather than things, with dynamic rather than static relations. The development of new knowledge must reflect a world in which everything is related to everything else, in which a confused myriad of quantitative changes gives rise to qualitative change, and so forth. Scientific work is thus inherently dialectical, whether or not the scientist recognizes this. Hence, unless political prejudice intervenes, the practicing scientist may have no difficulty agreeing *in an abstract way* with the simple basic concepts of *dialectical materialism.* "But", as Engels says, "to acknowledge this fundamental thought in words and to apply it in reality in detail to each domain of investigation are two different things." [*Feuerbach*, pp. 44-45.]

This journal aims to help scientists learn to apply dialectical materialism in a practical and useful way to their own particular domains of investigation. For this purpose, *Science and Nature* takes partisan positions on the basic philosophical issues of contemporary science:

1) Though the scientific method can carry us ever closer to the deepest secrets of nature, there is no such thing as absolute knowledge; any system of ideas that pretends to be complete and closed must inevitably become a brake on scientific progress, a source of mystification for science itself as well as for society as a whole. A prime example is the prevailing acausal interpretation of quantum mechanics, now spilling over into biology via Jacques Monod *et al.* The philosophical answer to this problem is to recognize "the necessary limitation of all acquired knowledge, of the fact that it is conditioned by the circumstances in which it was acquired." [*Ibid.*] The methodological solution to the problem is to keep every aspect of science open to critical discussion and free debate, to recognize that all scientific theories and interpretation of empiric results are products of human ideation and thereby subject to change and development in the quest for deeper knowledge. (To question whether a given theory represents absolute truth does not imply denying its material usefulness in the realm to which it applies.)

2) The motive power for change and development *within* science is generated by its own inner tensions, by the contradictions between the material basis of science and its own ideological superstructure, that is to say, between experiment and theory, between empirical data and interpretive model, between objective procedure and subjective social being in the professional activities of science. Mechanists pretend to eliminate this subjective aspect. Idealists contend that the subjective is all. Marxists maintain that the subjective component must be considered

integral to the interactive process of developing new knowledge.

3) On the other hand, the scientific enterprise also develops in dynamic two-way interaction with society as a whole, responding to needs and pressures from without and in turn creating the basis for vast new technologies and new concepts influencing the ambient social environment. Thus science is very much a part of living history, in which the social use and misuse of scientific knowledge depend on what prevails in the economics of funding, the politics of appointments, and the ideology of dominant class interests. It is nevertheless possible for scientists to band together in order to combat destructive applications of knowledge, to develop alternative ideas and institutions on the basis of unmet social needs, and to raise the social awareness of other scientists in the course of such struggles.

4) The process of science represents a relatively recent and very specialized form of human consciousness, one of the highest products of civilization and yet subject to distortion just as any other form of social consciousness. A fundamental function of philosophy is to help improve the ability of the scientist to recognize such ideological distortions in the consciousness of a scientific community and to track down the social-historical origins of such distortions, whether they arise from processes within the scientific community or from interactions with external society. For this type of consciousness raising, the Marxist principles of historical materialism provide uniquely effective conceptual tools, enabling the scientist to perceive and thus escape from the bondage of historically conditioned scientific ideas that have outlived their period of usefulness.

5) The use of historical materialism to confront *inner* problems of science, as proposed above, is not the only such potential application of Marxist philosophy that remains as yet very little explored or exploited. The primary purpose of this journal, stated above, implies helping scientists to acquire the depth and subtlety of understanding necessary for the application of this philosophy correctly, enabling them to steer carefully between the Scylla of mechanistic materialism and the Charybdis of dialectical idealism. If our journal succeeds substantially in this undertaking, it will no doubt contribute also to new insights and further development in Marxist philosophy itself.

Hank Talkington

P.S. Here some current philosophical views of the ongoing struggle:

The realist: "He who fights and runs away may live to fight another day."
The pragmatist: "I've been needing to do some jogging anyway."
The subjective idealist: "Victory and defeat are only states of mind!"
The objective idealist: "God knows why this had to happen to me!"
The neopositivist: "Give me a dignified symbol for the escape process."
The operationist: "What were the steps that got me into this dilemma?"
The logical empiricist: "Defeat is nothing more than negation of victory."
The mechanistic materialist: "Stop manipulating my fight/flee mechanism!"
The dialectical materialist: "How can we transform this into a new ballgame?"

The essence of consciousness

There were some men concerned only
with studying
profound books, in love with science,
and other men whose soul was action.
Lenin had two wings:
action and knowledge.
He created thought,
deciphered mysteries,
ripped off the masks
from truth and from man:
he was everywhere
at one and the same time, everywhere.
-- Pablo Neruda, "Ode to Lenin" 1957.
Tr. by David Laibman et al. (excerpt).

In itself the *scientific mode* does not attempt to make people want to do one thing rather than another. That is more properly the task of the *artistic mode*, a mode equally social, one of whose functions it is to generate first the wish and then the will for specific action. Neither of these modes is complete without the other and, in fact, neither in science nor in art is one to be found without the other. Nor between them do they exhaust the significance of art or science for the individual. Beyond them, and common to all forms of human achievement, is the intrinsic pleasure produced in the contemplation, or still more in the creation, of new combinations of words, sounds, or colours, or in the discovery of combinations already existing in Nature. -- J. D. Bernal, *Science in History*. M.I.T. Press 1971, p. 41.

Man's consciousness not only
reflects the objective world,
but creates it...
The world does not satisfy man
and man decides to change it
by his activity...
Practice is higher
than (theoretical) knowledge,
for it has not only
the dignity of universality,
but also of immediate actuality.
-- Lenin interprets Hegel,
Philosophical Notebooks, pp. 212-213.

Art, like science, also plays a cognitive role in respect of the phenomena of social life. Realistic art, like science, can tell us about deep-going social processes and the psychology of a particular class. But unlike art, which always expresses the general through the individual, the concrete, science presents it in the form of abstract logic, by means of concepts and categories....

Under communism science...and art will achieve new heights of development as the two different and complementary means of knowing the world. Their interconnection and interaction will increase. Even now science exerts a growing influence on the process of aesthetic perception and appreciation of the world by the broadest masses of the people.

Thus the growth of the role of science in the life of society will lead in the course of time to its occupying a leading place in the whole system of social consciousness and exerting an ever increasing influence on the development of social being. -- F. V. Konstantinov et al., *The Fundamentals of Marxist-Leninist Philosophy*. Progress, 1974, pp. 509, 532-33. □