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Conceptual Foundations of Quantum Field Theory

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Conceptual Foundations of Quantum Field Theory (Ed. Tian Yu Cao) (Cambridge: Cambridge University Press, 1999) 399 p.

The book under review is the proceedings of a symposium dedicated to the conceptual foundations of quantum field theory (QFT), which was sponsored by the Center for Philosophy and History of Science, Boston University and held at Boston University on March 1 – 3, 1996. The Symposium sought to provide an opportunity for physicists at the forefront of the QFT to present their views on the foundations of this theory and to discuss with philosophers the historical and philosophic aspects relevant to the consideration of these foundations.

Admittedly, the dialog was not an easy one. Referring to the Symposium proceedings, relations between the physicists and the philosophers were rather tense. Tian Yu Cao (Department of Philosophy, Boston University, Boston, USA), a philosopher of science and the principal organizer of the Conference, noted that certain physicists regarded the encroachment of philosophers into the province of the QFT physics with suspicion while certain philosophers were disappointed by the fact that contemporary physicists avoid considering deep metaphysical problems, even those raised by Einstein and Bohr, and have entirely devoted themselves to the solution of purely technical problems of the theory. Many of the Conference participants (M Redhead, Cambridge University, UK; T Cao; C Rovelli, University of Pittsburgh, USA) believe that philosophers can contribute much to the elucidation of conceptual foundations of QFT, but they go along with those physicists (S Coleman, Harvard University, Cambridge, USA; M Fisher, University of Maryland at College Park, USA; etc.) who say that to do so philosophers should first learn physics well.

That this knowledge alone is not all that is required catches the eye when one familiarizes oneself with the Symposium proceedings. Among the philosophers participating in the discussions were researchers with an excellent understanding of modern physics, as proven by the presentations they made. Reports were made by the aforementioned T Cao and M Redhead who discussed the philosophical aspects of QFT and demonstrated a deep understanding of the physics of the quantum field theory; R Healey (University of Arizona, USA), whose contribution was entitled "Is the Aharonov – Bohm Effect Local?"; Paul Teller (University of California, USA), whose paper was entitled "The Ineliminable Classical Face of Quantum Mechanics"; N Huggett (University of Illinois at Chicago, USA) and R Weingard (Rutgers University, USA) made a joint report entitled "Gauge Fields, Gravity and Bohm's Theory"; S French (University of Leeds, Leeds, UK), who made a joint report with the mathematician D Krause (Federal University of Parana, Brazil) on "The Logic of Quanta"; etc. In this case, the physicists advanced no serious criticism of any value concerning the philosophers as regards the purely physical content of the problem. The philosophers communicated with the physicists 'on equal terms'.

Some tension nevertheless did exist. There might be other reasons for this — supposedly professional and psychological. It was not without reason that one of the physicists, C Rovelli, reproached some of his guild-brothers for assuming the attitude of a lecturer towards the philosophers and urged them to view the philosophical problems arising in present-day physics seriously. Philosophical terms like, e.g., 'instrumentalism' or 'ontology' should not be rejected on the spot for the sole reason that they are unknown to us or are devoid of clearly defined borderlines. Rovelli said, "In order to have a dialog, we have simply to learn the meaning of words used by the other side" (p. 286). He urged physicists to speak more openly of the unresolved problems existing in contemporary physical knowledge, for they can be solved only by way of open discussions, including those with well-educated philosophers of science.

In this connection a remark is appropriate, which to a degree forestalls the consideration of the conference materials. It applies to the evaluation of the conference by some of its participants. In particular, T Cao stressed that, in order that a fruitful dialog could take place, both sides (physicists and philosophers) should step over the threshold of their ambitions. We are, however, more optimistic in the assessment of the results of the conference: not only *could* the dialog take place, but it *did* take place, even contrary to the subjective intentions of some of its participants. It turned out that discussing physical problems inevitably involves entering the realm of philosophy, epistemology, and metaphysics, while a philosophical discussion implies, or calls for, invoking the material of the physics itself.

Several outstanding representatives of contemporary science took part in the conference on the part of physicists. Among them were Nobel Laureates — S Weinberg (University of Texas at Austin, USA) and S Glashow (Harvard University, Cambridge, USA) — and also such prominent physicists as B DeWitt (University of Texas at Austin), D Gross (Princeton University, Princeton, USA), R Jackiw (Massachusetts Institute of Technology, Cambridge, USA), S Coleman, A Jaffe (Harvard University, Cambridge, USA), A Wightman (Princeton University, Princeton, USA), F Rohrlich (Syracuse University, USA), C Rovelli, and M Fisher. The participation of these scientists ensured a high theoretical level of discussions of the QFT foundations, including historical, philosophical, and metaphysical aspects of the theory.

It is well known that the QFT is the theoretical paradigm of contemporary basic physics: elementary particle physics and cosmology. It made the most significant advances in the early 70s, which saw the advent of the so-called Standard Model (SM) capable of describing the fundamental interac-

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tions of nature in the framework of a unified theoretical structure — non-Abelian gauge theory. However, a long period of stagnation succeeded the establishment of the SM: apart from a detailed experimental verification of the theory, nothing of any conceptual significance evolved.

As noted by T Cao in his paper, this situation receives different appraisals, depending on the prospects envisaged by a particular researcher. The apologists of the standard model insist that physics may be thought of as being complete. They believe that all the basic laws have been discovered and classified in the standard model. "No new physics!" is their slogan.

Other researchers do not share this viewpoint. They point to the drawbacks of the standard model. Pinpointing the situation, S Glashow even stated: "In fact, QFT is just wrong!" (p. 77). The right theory should incorporate quantum gravitation (for the quantum theory is all-embracing!). But QFT has not even approached the solution of this problem. Moreover, there exist many other problems. One of them is the divergence problem. "To such luminaries as Schwinger and Dirac, the appearance of divergences make QFT unacceptable as a final theory," noted Glashow (p. 77). These problems may be solved when (and only when) the SM is derived from the superstring theory. One source of divergences — discrete space – time points at which emissions and absorptions take place — is eliminated in the string theory. Moreover, the string theory incorporates gravitation. But "nobody has been able to wring from it any explicit and testable predictions," reminds Glashow.

Many speakers emphasized other well-known difficulties and problems encountered by QFT. There exist too many empirical parameters that cannot be calculated from the basic principles of the model and are introduced 'by hand'. The interaction unification achieved in the context of the SM is only partial: for quark – gluon interactions, even the electroweak theory and quantum chromodynamics remain separate, to say nothing of the gravitation. The critics of the SM are convinced that the theory's stagnation is merely the calm before the storm: a new conceptual revolution is approaching, which will not necessarily be tied to the ideas of the string theory but in any event will signify a radical reconsideration of the basic assumptions and principles of QFT.

This opinion was voiced by D Gross in his report entitled "The Triumph and Limitations of Quantum Field Theory". He noted that the SM describes experimental data with high precision. In quantum electrodynamics, the agreement is reached to the tenth significant figure; in weak interactions to the fourth significant figure; and in strong interactions to the second. In specific experiments on quantum electrodynamics, the theory was verified to distances of 10^{-18} cm. Gross analyzed the problems facing this theory to subdivide them into those which can be solved within its framework and those which indicate the limits of validity of QFT and necessitate going inevitably beyond its limits. Among the latter are the problems of interaction unification, mass hierarchy, and origination of leptoquark families; the explanation for the parameters of the standard model and the low magnitude of the cosmological constant, the reconstruction problem of the early history of the Universe, etc. In the view of Gross, physics is now on the threshold of a scientific revolution: too many a basic physical principle has been defied and too many a basic notion stands in need of reconsideration. He believes that the future development of physics will be related to the elaboration of the string theory.

In a sense, S Treiman (Princeton University, Princeton, USA) advocated the SM. In his comment on Gross's report he noted that, when criticising the SM, one should not overlook its flexibility. It may be generalized to such a degree as to permit the existence of finite neutrino masses, additional Higgs particles, and even new particle families, if need be. It may be developed to such a degree as to permit the unification of electroweak and strong interactions and even the incorporation of the idea of supersymmetry. Treiman admitted, however, that there is a kernel of good sense in Gross's critical attitude to the SM: this model is far from being an 'economical' one. The choice made on its basis is quite often found to be arbitrary. For instance, we cannot explain in the context of quantum chromodynamics why the gauge group is SU(3) and not some other symmetry group; there are problems with mass hierarchy and also with the large number of parameters introduced, etc. But the greatest problem for the SM is undeniably the problem of quantum gravitation. It is widely believed that 'quantum gravity cannot be successfully married to quantum field theory'. According to D Gross, there are grounds to believe that this 'marriage' is possible in the context of the string theory. However, Treiman believes that, no matter what theory may supersede the QFT, on a sub-Planck (as regards energy) scale it is certain to turn into QFT.

And, finally, mathematically oriented physicists believe that solving the challenging QFT problems is feasible only by using more rigorous and exact mathematical schemes. This viewpoint is shared, in particular, by A Wightman, who in due time laid the foundations of the QFT axiomatics. Wightman believes that the scientists working at the forefront of science are quite often unaware of exactly what they are doing, for the available experimental data are, as a rule, incomplete and ambiguous while the theoretical notions in use still lack an explicit formulation. In this connection he emphasized the need to revise and refine the theoretical scheme in order to endow it with the highest possible mathematical rigor and exactness, even though we may have to reconcile ourselves with some of its drawbacks from the standpoint of physics.

The question of the role of mathematical methods in present-day physics was addressed by A Jaffe, who noted a new trend in the interrelationship of these two realms of human knowledge. Mathematics has traditionally been perceived as the language of physics. At this stage of development of science it is valid, he believes, to reverse the well-known E Wigner's aphorism about 'the unreasonable effectiveness of mathematics in the natural sciences'. The time has come to speak about the unreasonable effectiveness of theoretical physics in mathematics. Many papers have appeared in which physics gives birth to new mathematical ideas. It has been recognized in the 80 – 90s that not only is mathematics the language of physics, but physics is becoming the language of mathematics as well.

As a matter of fact, Wigner's aphorism proved to hold much favor at the conference. 'The unreasonable effectiveness of QFT' was spoken of in a paper of the same name by R Jackiw. He arrived at the paradoxical conclusion that the infinities of the local QFT, which are usually regarded as drawbacks of the theory, are in reality the source of its efficiency, its ability to describe and interpret physical phenomena. The same expression was used by Glashow when he spoke about the extraordinary, fantastic effectiveness of QFT as a computational tool. And once again, 'the unreasonable effectiveness', this time of the physicists' intuition, was addressed in F Rohrlich's report.

Both philosophers and physicists discussed the metaphysical and epistemological physics issues. Among the metaphysical ones is the question of the picture of the world drawn by modern physics. Is the world continuous or is it inherently discrete; what is the significance of the notions of wave and particle in the subatomic world; what is the nature of vacuum and vacuum fluctuations; is the world homogeneous or hierarchical in structure; if the latter is true, what are the mechanisms of interaction between different hierarchy levels: can they be characterized in terms of reductionism or should we admit that they cannot be reduced to each other in principle?

Standing first on the list of epistemological questions is that of the nature of physical notions. Are they correct in treating these questions in the spirit of pure instrumentalism and in assuming that the destination of a theory is merely to describe observed phenomena and predict new experimental results; or are the realists correct in reasoning that at least some of these notions bear on reality? Most important for a realist is the question of the base ontology of the theory, i.e., of those conceptual elements in the logical structure of the theory that cannot be reduced to simpler ones. It is assumed that its base ontology describes, unlike the epiphenomena or heuristic and conventional components of the theory, reality itself.

Before considering the discussions around metaphysical questions, we enlarge on Glashow's report, who posed the question of the nature of the metaphysical questions themselves ('the metaquestions' in his terms). What are metaquestions, what is their significance for culture and society? Contrary to the title of his paper — "Does Quantum Field Theory Need a Foundation?" — in which Glashow as if casts doubt on the necessity of discussing the philosophical foundations of the QFT, the author addressed the problem from truly a philosophical standpoint. He recognized four types of questions which may arise concerning one or other scientific theory. The intrinsic questions — they can be solved within the framework of the theory. The emergent questions (here, in the sense 'unforeseen, qualitatively new'), which invite further development of the theory because they pose new problems. The empirical questions, which can be solved on the experimental level and do not call for invoking the theory. And the metaquestions, which cannot be solved in the context of the theory. Some of the questions that were metaquestions for QFT have received the status of internal questions and answers to them have already been provided. But there exist some that still remain metaquestions. Among them is Dirac's 'problem of large numbers'. Why do the masses of different fermions vary by five orders of magnitude? Why are they so small in comparison with the Planckian mass? And so on. Why are the interactions in the world of elementary particles described by gauge symmetries? What is the nature of the gauge symmetries themselves? What is the source of forces? Why are the gravitating and inert masses equal? Do electrons possess internal structure? And so on.

From Glashow's point of view genuine metaquestions have survived only in elementary particles physics and cosmology. Many branches of science pretend to the status of a basic discipline: condensed-matter physics, chemistry, molecular biology, etc. But Glashow believes that, in a sense, this is not so, for they are nearly free of metaquestions. However, the value status of metaquestions themselves, believes Glashow, has changed. In the past, securing answers to them led to major technological advances, whereas metaquestions have now become socially less significant. It looks as if the answers to them has no effect on the lives of ordinary people. They do not foster economic progress, nor do they improve the well-being of the people. Never will τ leptons or W bosons enjoy practical applications. Kaons were discovered half a century ago but have never been employed in human practice. "The virtues of science at the metafrontier are inspirational, intellectual and cultural, but they are anything but practical" (p. 80).

The QFT ontology problem (i.e., the question of what the base essences described by the theory are) was the concern of the reports made by S Weinberg, F Rohrlich, S French and D Krause, D Kaiser (Department of History of Science, Harvard University, Cambridge, USA), and T Cao.

In a presentation entitled "What is quantum field theory and what did we think it was?" S Weinberg gave a brief analysis of the basic propositions of QFT and the pathway of its historical development. For a long time physicists believed that the world consists of fields and particles: electrons are particles and the electromagnetic field is a field, though photons behaved like particles. At present the old dualism, according to which photons are something quite different from electrons, has been completely overcome. In the context of mature QFT quantum fields are the base ingredients of the universum while particles are merely manifestations of the fields. Therefore, QFT leads to a more unified picture of the world in comparison with the old dualistic picture of particles and fields. Nevertheless, notes Weinberg, the irony of fate is that many calculations in QFT prove to be simpler if they are performed in the context of the old views, following the world lines of particles rather than the time evolution of fields.

It is not unusual that physicists content themselves with a purely phenomenological answer to the question of what an elementary particle is: this is a particle whose field appears in the Lagrangian. It makes no difference whether the particle is stable or not, is light or heavy; if its field appears in the Lagrangian, it is elementary, if not — compound. Weinberg by his own admission no longer contents himself with such an answer. His long-term teaching experience has led him to the conviction that physics should not merely describe the world; its task is to explain the world. Weinberg sees a rational justification of the theory formalism in that this is the only way to accomplish the synthesis of principles — those of Lorentz invariance, quantum mechanics, and cluster decomposition. S Weinberg defines the principle of cluster decomposition as the requirement that 'distant experiments give uncorrelated results' (p. 243). The entire formalism of fields, particles, and antiparticles of QFT is presumably an inevitable consequence of these principles. Any quantum theory that is Lorentz-invariant for sufficiently low energies and long ranges and satisfies the cluster decomposition principle would look like QFT.

QFT adequately describes experimental data for soft pions — up to gigaelectron-volt energies; for superconductivity — up to Debye frequencies; for the SM — up to 10^{15} GeV; and for gravity — up to 10^{18} GeV. What will become of an effective field theory when energies above 10^{15} GeV are obtained? Weinberg anticipates two possible variants of development. The first may involve the origination of the problem of mathematical substantiation of the fixed point of renormalization-group equations. The way toward resolving this problem is so far unclear. More likely is the alternative:

for very high energies we will go into new physics not represented by QFT. This may be something like the string theory.

In his report entitled "On the Ontology of QFT", F Rohrlich called attention to how the significance of the 'particle' and 'field' notions changes in the passage from classical physics to quantum physics and to QFT. The classical particle – field dichotomy proves to be mixed in quantum mechanics (QM): here, particles are described by a wave function, which depends on the space – time and is therefore a linear field while the linear electromagnetic field of classical physics acquires features of particles (photons). Further changes occur as we pass from QM to QFT. In the operator formulation, the fields in fact 'gain the upper hand' and an effort is to be mounted to provide the corresponding description in terms of 'particles'. The theory is formulated in terms of fields and their interactions, the fields are primarily the object of theorists' attention. At the same time, experimenters observe only particles. Recorded at accelerators are particles and their properties. This is not self-contradictory because theorists know how to separate a particle from the field. But in this case mathematical problems emerge, for the Fock representation employed in going from a field to a particle is legitimate only in certain conditions. This does not signify that there is no way of going from fields to particles on the theoretical level; this merely implies that the passage is nontrivial. And, while the ontological status of an elementary particle is hardly doubted (it is accessible to empirical fixation), the question of what other components of the theory possess ontological status is highly conjectural.

S French and D Krause devoted their report to the problem of discernment and identification of quanta. Unlike classical physics in which objects can be discerned, counted, and ordered, in quantum physics this proves to be impossible. The indistinguishability postulate underlies quantum statistics. The classical set theories are inadequate for the solution of the quanta identification problem, because they assume particles to be distinguishable. As reminded by the authors, set is, according to famous Cantor's definition, 'collections into a whole of definite, distinct objects' (p. 324). As stated by the authors, understanding the nature of a quantum and the metaphysics underlying this notion calls for the development of a new logical means. As one approach to the solution of the problem, they believe it possible to use some special notion of a 'set' defined as a collection of indistinguishable though individual objects. The objects in such a 'set' possess the 'cardinal property' (we can specify their number), but are devoid of the 'ordinal property' (we cannot enumerated them or order them).

The work of a special section was dedicated to the discussion of the problem of space – time in QFT. A peculiar introduction to this problem was the report of J Stachel (Department of Physics, Boston University, Boston, USA). His report was devoted to the history of efforts to construct a quantum theory of gravitation. Special emphasis in the report was placed on the work of our compatriot — the physicist M P Bronshteĭn, who gave much thought to this problem from the early 30s until his tragic death in 1938. As stated by J Stachel, M P Bronshteĭn succeeded in making a significant contribution to the discussion of this problem. When developing the idea of quantization of gravity at that time shared by the majority of theoretical physicists, M P Bronshteĭn arrived at the conclusion that the existing formalism of field quantization was incompatible with the nonlinear gravitation theory and that constructing an adequate quantum theory of gravitation called for a radically new approach. In the view of J Stachel, the opinion that the problem of quantum gravity now stands in need of an unconventional approach is coming to be prevalent (p. 235).

Further discussion of the space – time problem was pursued by B DeWitt in his paper entitled "QFT and Space – Time — Formalism and Reality", by A Ashtekar (Pennsylvania State University, University Park, USA) and J Lewandowski (University of Warsaw, Poland) in their joint paper "QFT Geometries", and by C Rovelli in his paper entitled "Localization in Quantum Field Theory: how much of QFT is compatible with what we know about space – time?"

C Rovelli pointed out that the contemporary picture of the world, which rests on the notions of QFT, leaves open such important questions as to what are time, space, causality, and matter. Einstein's general theory of relativity (GTR) changed our notions of time and space; the same was done by quantum mechanics with the notions of matter and causality. So far the problem of unification of quantum mechanics and the GTR has not been solved and we do not have a consistent picture of the physical world today. If the space–time continuum breaks down in time units at a level of 10^{-40} s, as is fixed each time in attempting to unify the GTR and quantum mechanics, it turns out that the world is inconceivable as developing in time. The vanishing of time is dramatically evident in the mathematical formalism of the theory — both in the 'unperturbed' canonical gravity and in the 'unperturbed' string theory. The time parameter is absent in the basic equations of both theories. Quantum mechanics, on the one hand, and the GRT on the other destroyed the notions that underlay the great synthesis of the Cartesian – Newtonian picture of the world. But we do not have a new synthesis. We have impressive areas of fragmentary knowledge but not a general picture. We do not know what we should think about space, time, and matter so that it is compatible with everything we already know. And, as Rovelli believes, philosophy with its aspiration to the analysis of the foundations of the new paradigm emerging in physics can play an important part in searching for the answer to all of these questions (p. 228).

B DeWitt spoke about the relationship between the mathematical formalism and reality in the interpretation of space – time. Since the notion of field was introduced in physics, physicists would ask themselves the question of whether the field is a purely mathematical representation of a more basic reality or the field itself is a physical essence filling the absolute Newtonian space. Maxwell regarded the electromagnetic field as a physical reality but was reluctant to ascribe it an independent existence as some 'non-mechanical essence'. Einstein proposed that the gravitational field should be treated as the curvature of the space itself and sought to elaborate the geometric theory of even the electromagnetic field. The mathematical conception of field is in fact employed in quite different contexts and distinct field conceptions are our only windows into reality.

How did we proceed previously? We started out with fields — scalar, vector, and spinor ones — in normal time and space. We then passed on to fields (Schrödinger fields) in a space of $3 + 1$ dimensions. DeWitt calls attention to several structurally nontrivial infinite-dimensional spaces: Hilbert space and Fock space. There also exist higher finite-dimensional spaces, which can be found in the Kaluza – Klein theory, supergravity, and string theories. Which of these fields embody reality? In the view of DeWitt, it would be premature to state that reality is embodied in an integral mathematical structure (we do not have a theory of everything); to be more precise, our comprehension of reality, no matter how imperfect it may be now, demands for an integral mathematical structure. We should always endeavor to develop the mathematical formalism of a physical theory and its internal logic to some final result. We should allow the logic to lead us through, in this case not overlooking corrections on the part of experimental physics. Eventually we will not necessarily reach an exact description of reality, but we will arrive at the best description that we can obtain (p. 182).

It may be that the problem debated most hotly was that of reductionism – antireductionism in the theoretical reconstruction of the microreality. Will physics content itself with the program of effective field theories or will it necessarily search for a final theory? The assumption that the program of effective theories is the only correct strategy of scientific cognition signifies recognition of the fact that the world is hierarchically organized and there exist different levels of this hierarchy, which differ in length and energy scales. Though these levels are interrelated, each of them is quasi-autonomous. The behavior of the microobjects that 'inhabit' a level obeys its own laws. In accordance with the program of effective theories, the dream of some final theory should be abandoned. Unlike the final-theory strategy, the program of effective theories is antireductionist.

An antireductionist point of view was followed by the above-mentioned F Rohrlich. For a long time there existed a requirement that 'lower-level' (more basic) theories should serve as the basis for the 'higher-level' ones. This is a requirement of reductionism. As stated by Rohrlich, this requirement has repeatedly exhibited its inconsistency in recent years. Higher-level theories contain notions that are meaningless on the basic level. They cannot be logically deduced from the lower-level notions. They have to be invented. Rohrlich believes that reductionism is disproved, for instance, by the following fact: in reality, the theory of condensed matter does not invoke the basic-level notions, such as quarks and leptons, and nevertheless has been making rapid strides in recent years. Antireductionism implies the recognition of scientific pluralism. And this leads to significant implications as regards the very notion of truth. In science, to state that something is true is meaningless without making reference as to which cognitive level is involved. Rohrlich states that a "scientific truth is not necessarily meaningful outside its cognitive level" (pp. 358 – 359).

D Nelson (Harvard University, Cambridge, USA) and R Shankar (Yale University, New Haven, USA) also held the antireductionist viewpoint. Both speakers emphasized the fruitfulness of the effective-theories strategy. They stated that progress in physics is quite often made by departing from the search for the basic theory and turning to an effective one. In doing this they referred, like Rohrlich, to the physics of condensed matter. Elementary particle physics strives to reach so small a length scale and so high an energy range that its conclusions, while retaining beauty, prove to be insignificant for the physics of the world that surrounds us, advocated D Nelson. He cited the words of David N Mermin who compared the experiments on the new-generation accelerators with archaeological excavations into an extremely remote age in the early history of the Universe. The connection of these excavations "with cosmology is thrilling," remarked Nelson, "but the results are about as relevant to the way matter behaves today as newly discovered shards of ancient Sumerian pottery would be to the next presidential election" (p. 265).

S Weinberg raised objections against the antireductionism of Rohrlich. "I think that it is a non-sequitur to say that because certain concepts at one level don't exist at a more fundamental level, that the laws governing these concepts cannot be deduced from the more fundamental level... Even though the concept of temperature does not exist at the particle level, we understand why there is such a concept and we understand how it works, in terms of a deeper level" (p. 261).

Weinberg advocated the feasibility and the necessity of constructing a final theory. D Gross took up the same standpoint. Both scientists believe that all the effective field theories are merely approximations, obtained for the low-energy range, to a more profound theory, which will soon be derived from these approximations in some systematic way. However, both of them believe that this more profound or final theory will be similar to the string theory or some other theory radically different from QFT.

M Redhead, a philosopher of science, also proceeded from a reductionist standpoint. He noted that neither the antireductionism, which is associated with the 'tower' of effective theories that goes to infinity, nor the reductionism, which implies a final theory of the theory-of-everything type, cannot be substantiated experimentally once and forever. Nor can the ideas of atomism (Democritus) and continuity (Aristotle) that go back antiquity receive their ultimate substantiation. All these ideas are metaphysical in character; for, in Kant's words, they go beyond the scope of any conceivable experience. At the same time, the idea of atomism and the related idea of a final basic theory are the most important regulative principles of a cognitive process. They send a scientist searching for the unity of knowledge in the course of his cognitive activity. The search for inherently simple and symmetric order that underlies the seemingly complex world of phenomena is the ever-reproducing trend of science methodology. In the view of Redhead, to sign up to the new program of effective theories implies abandoning these aspirations and reverting to a standpoint that is more pragmatic, cautious, and close to experimental practice and yet significantly less thrilling intellectually (p. 40).

Replying to the challenge of reductionists, T Cao noted that antireductionism and the program of effective theories by no means imply rejecting the idea of a basic theory and the triumph of a purely phenomenological approach to the study of a subatomic world. The strategy of effective theories, which negates monofundamentalism, is compatible with polyfundamentalism and the acceptance of the existence of many levels each of which is basic (fundamental) and none of which can be regarded as being more fundamental than the others. An investigator of each of these levels can endeavor to find the law and the order which underlie the phenomena of the level and enjoy the beauty of the generalizations arrived at, even though he may realize that his fundamental theory is of limited application. And this should not discourage him. For even the most consistent monofundamentalist in elementary particle physics realizes that his theory is of limited utility and cannot be used, say, in economics or poetry (p. 33).

And, finally, the antireductionistic viewpoint is shared by Glashow, who calls himself a phenomenologist of principle. A specific epistemological standpoint underlies Glashow's phenomenologism. He casts doubt on the significance of the very notions of a 'final' theory or a 'theory of everything'. Though he agrees upon the fact that the ideal of a final theory plays a positive role in cognition by stimulating the greatest intellectual efforts to construct the theory, the goal itself is illusive. He does not believe that scientists will ever achieve it. "Nonetheless," Glashow makes an elegiac remark, "the trip is wonderful and the landscape so breathtaking" (p. 82).

With these wonderful words, with which any genuine scientist would undoubtedly agree, we conclude our inevitably brief review of this interesting forum of scientists. In summary, we would like to note that reading this book is not only useful, but pleasant as well: it harbors numerous references to our compatriot – physicists — V A Fock, L D Landau, V L Ginzburg, N N Bogolyubov, D I Blokhintsev, Yu I Manin, M P Bronshteĭn, etc., who made an inestimable contribution to the progress of theoretical physics.

P S Isaev, E A Mamchur