COMMITTEE II
Synthesis and Relationships in Culture

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DISCUSSION REMARKS

by

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on

Luigi Accardi's

THE ROLE OF MATHEMATICS IN SCIENTIFIC SYNTHESIS AND THE INTERPRETATION OF QUANTUM THEORY

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In the first part of Accardi's paper it is outlined that in the history of science, and of physics in particular, the corner-stones are often recognized as unifications. Unifications into a single descriptive scheme, or more specifically into a single theory, of phenomena originally considered as belonging to different descriptive schemes, or different theories. Famous examples can be reminded: the unification between the forces that cause an apple (to quote the object of Newton's anecdote) to fall on the ground and the forces that bring celestial bodies like planets and satellites along their trajectories; the unification of electric and magnetic phenomena; the unification between thermodinamics and the underlying mechanics of assemblies of atoms or molecules; the unification of notions like energy and mass provided by relativity theory; the more recent unification of electromagnetic and weak interactions.

These unifications seems to offer the most convincing meaning one can give to the notion of synthesis in science.

With quantum theory things are especially complex. Together with Einstein's relativity theory quantum mechanics is regarded as the greatest achievement in physics in this century. It came into play, more than fifty years ago, to explain the non-classical phenomenology of atomic physics and partly of electromagnetic radiation, but then it proved to encompass classes of very far phenomena: from macroscopic ones like superfluidity to those that lie on a much smaller geometrical scale, i.e. nuclear and sub-nuclear physics. The power of quantum mechanics in predicting and accomodating empirical data is impressive and no counterexample is known. In recent years, under the developments of the old issue of whether the intrinsically probabilistic structure of quantum mechanics could admit an underlying deterministic theory (a so-called hidden-variable theory), subtle experiments have been proposed and performed on polarization correlations in two-photon atomic cascades and, once more, agreement with the predictions of quantum theory have been found. Owing to its general successfulness quantum mechanics represents a most remarkable synthesis in the scientific thought. Yet, its traditional formulation and interpretation contains, as discussed in Accardi's paper, puzzling dichotomies that call for some further synthesis. A celebrated example is the wave-particle dualism: the behaviour of quantum physical objects exhibits properties that fit into the descriptive scheme of waves as well as properties fitting the one of particles. From a slightly different point of wiew we might say that an uncomfortable feature of the traditional interpretation of quantum mechanics is the role of the observer on the properties of the physical system under attention, for instance the claim that the physical system might loose some properties when nobody is looking at it.

In the history of physics the emerging theories have been usually formulated by using the concepts and the language of the theories to be superseded: some time is generally required before a new theory acquires autonomy and internal coherence. This period of time has been unusually long with quantum mechanics: the very persistence of a debate on its interpretation proves that a generally accepted solutions is not yet at hands. The way proposed by Accardi to make quantum theory conceptually autonomous and internally coherent is to frame it into a generalization of classical probability theory, called quantum probability. Such a generalization goes through the dismission of the classical definition of conditional probabilities according to which the probability P(A/B) of the event A given that B has occurred is given by

$$P(A/B) = \frac{P(A \cap B)}{P(B)} .$$

This formula is regarded as unjustified in the domain of quantum theory where it cannot be experimentally checked. Thus, quantum probability originates from a non-classical assumptions on how the probability evaluations about a physical system change under the record of new information on the system.

The dismission of classical probability theory appears as a necessity, in the sense that given a set of statistical data it is not a matter of taste the choice of a probabilistic model able to match them. One of the main facts in Accardi's approach is that, from the set of statistical empirical data, certain "statistical invariants" can be derived which are able to single out the probabilistic model that matches the data; in particular it can be specified which conditions the statistical invariants have to fulfill in order to single out the quantum probability model.

The growth of quantum mechanics is intertwined with the creation a new branch of mathematics: the functional analysis. According to Accardi the achievement of full conceptual autonomy and internal coherence by quantum theory is associated with the appearence of another mathematical tool: the quantum probability.