INTRODUCTION

The purpose of this book is to initiate a new discipline, namely *a formalized epistemological method* drawn both from the cognitive strategies practised in the main modern sciences and from general philosophical thinking. Our progress in this direction will be attempted by general discussions concerning the concept itself, by constructive attempts, and by informative-critical explorations. Our goal has been triggered by the following considerations.

Everywhere at the present frontiers of scientific thought one can watch how absolute assertions and absolute separations that formerly seemed unshakeable are fading away.

So, for instance, in logic and mathematics the belief in the possibility of an uninterrupted progression of unlimited purely formal developments, which dominated the beginning of the last century, has collapsed. It has become clear that any definite domain of exclusively formal action is confined, even if in principle it can always be extended, while the process of extension itself escapes formalization, as also, quite radically, the process of creation of a domain of formal operationality does.

For living systems, the definition of what is called the system raises nontrivial problems. Biologists have been led to introduce notions like "self-organization" and "organizational closure" in order to point the way in which a living system constantly re-constructs its own matter, forms, and functions by processes where the feedback upon the system, of its interactions with the environment, are as important as the characters of the system itself.

As soon as life is involved, the concept of cause resists any attempt to clearly distinguish it from the concept of aim. For living beings as well as for those meta-living beings called social organizations, the importance of pragmatic models conforming to aims located in the future but shaping the actions accomplished now in order to reach the aims, becomes decisive. The aims—tied to belief and anticipation—operate backwards upon the action that furthers the aims, whereas the action, while it develops, changes the aims. This entails a dynamic that depends upon its history and its context, and of which the characterization requires a cognitivistic and evolutionary approach.

The theory of (the communication of) information deals with the transmission of messages by making use of a probabilistic representation of a peculiar sort, according to which any received message unavoidably depends not exclusively on the message sent but also on the "channel" used in the

process. Thus the message received is quite fundamentally dependent on the way in which it becomes perceptible to the receiver. As a consequence, the possiblity of reconstructing the sent message out of the received one has to be studied explicitly as a function of the modalities of transmission; and the conditions required for such a reconstruction are highly nontrivial.

The investigators of "chaos" have resolved a millenary confusion by elaborating abstract mathematical examples, on the one hand, and simulations, on the other hand, which prove that determinism does not entail predictability: Deterministic modelings, and the full recognition of the randomness of the facts such as they are directly perceived by us exist side by side in mutual independence. Thus the fictitious belief that a choice has to be made evaporates, and a world of new questions arises concerning a pertinent representation of the relations between perceptual randomness and deterministic models of physical processes.

In the approaches concerning the treatment of "complex" systems or processes, the "agents", their "environment" and "actions", and the feedbacks from these, constitute inextricably entwined hierarchies of matter, situations, conscious aims and behaviours, knowledges, social organizations, and devices. What is named how, what is treated how, becomes a matter of *method* much more than a matter of fact. The boundaries between categories with fixed inner content fade away, and *roles* take their place.

And so on. We could continue the list. Everywhere the contours of separations that seemed obvious, clear-cut and absolute become shaky and full of gaps. And these superficial symptoms make us feel that we are witnessing changes which, though superficially appearing to be unrelated, are connected beneath the level of the directly perceptible. We also feel that the implications of these changes go down very deep, that they touch and modify the slopes of the first layer of our conceptualization, the very place where the general structure of our modern way of thinking and speaking has been forged. But the nature of changes of this sort—precisely because they concern established manners of thinking and speaking—is very difficult to grasp by use of the established manner of thinking and speaking. So the existence of these changes is revealed by their effects long before we become able to discern and express their precise content.

The very existence of these changes as such, before any attempt to define their contents, already raises questions. The conceptualization by man, of what he calls "reality", is itself an element of "reality". Is it then not subjected to some *laws*, to some *in*variances? This should be the case in some sense; but in which sense exactly? What changes and what stays the same? How could one delve deep enough, and how should we proceed in order to be sure that we capture and fully seize the essence of the develop-

ing transmutation as well as the stable structure that meanwhile persists? Without permitting decades to pass while the process is accomplished implicitely by osmotic assimilation of random, disparate bits of knowledge and interactions among them, without generating any perceivable contour?

It would be of crucial utility to succeed. Only what is explicitly known acquires a definite form, perceptible from the "outside". And only once this happens does it become possible to then detach what has been formed, optimize it with respect to definite purposes, and shape it into a genuine instrument that can be deliberately employed and indefinitely improved.

At the beginning of the last century, the theory of special relativity reduced the structure of the concept of spacetime that underlies the descriptions of physical phenomena, in the sense that the fracture of a bone is reduced by a surgeon. And later, starting in 1924, quantum mechanics crafted conceptual-operational-formal channels that have enabled the human mind to apply itself directly to the unobservable and to construct concerning it observable predictions that are realized with impressive precision. Of course, these are arcane revolutions which so far have penetrated the thinking of only a very few people. Moreover, they are as yet unfinished revolutions. But some philosophers, helped by a small number of physicists, have generated a process of communication by which, osmotically, the essence of some views of modern physics has more or less infused many minds. The germs of new approaches that are developing in various areas of scientific investigation have sprouted in this modified earth, which has nourished their further growth.

I now make the following possibly surprising assertion, which I hold to be crucial:

> *Quantum mechanics, like a diver, can take us down to the level of the* `very first` *actions of our conceptualization of reality. And starting from there, it can induce an* `explicit` *understanding of certain fundamental features of the new scientific thinking.*

The following remarks can give a first idea of the content of this assertion. Our way of conceiving the "object", which is what we separate from the "rest" in order to enable us to definitely examine and reason about it, marks our whole way of thinking as well as all our actions. Now, intuitively, the word "object" is still quasi-unanimously felt to be essentially tied to invariance, material, morphological, and functional, and thus to what could be called an "intrinsic objectivity", independent of observation, pre-existing such as it is perceived. More or less implicitly, all of current language and the entire classical logical and probabilistic thinking are founded on this presupposition. But quantum mechanics opposes a direct, radical and definitive

veto of this presupposition. If its cognitive strategy is fully decoded and conveniently generalized, the formalism of quantum mechanics acts like a strong magnifying lens under which the static contour of the classical concept of object dissolves into a complex *process* inextricably tied to human cognitive actions, most usually reflex actions, but often also deliberate ones; and, in any case, the result of this process is indelibly marked by *relativities* to all the cognitive actions involved. In essence this conclusion has been known well for a long time. But the specific way in which quantum mechanics conveys this old conclusion is new, and it amounts potentially to an overt seizure by *physics* of the basic metaphysical question of realism. Physics thereby merges with philosophy in a basic, massive way, and it injects into philosophy a stream of innovation that leads directly into epistemology :

> *Quantum mechanics has captured and represented—for the particular case of microstates and in an implicit, cryptic way, but for the first time in the history of human thought and directly in mathematical terms—certain* `universal` *features belonging to the* `very first stage` *of the processes by which man extracts chains of communicable knowledge from the physical reality in which he is immersed and of which he partakes.*

This is what the epistemological universality of quantum mechanics consists of. By no means does it consist, as is often asserted, of the fact that any material system is made of microsystems—which is a physical circumstance, not an epistemological one. The feeling of essentiality conveyed by the quantum mechanical formalism to those who can read it, does not stem from this physical circumstance; it stems exclusively from the universal character of the *peculiar cognitive situation* dealt with in quantum mechanics. And, while reflections of it are encrypted in the general features of the formalism considered as a whole, this cognitive situation marks also directly the specific formal features that are pointed toward by the expressions "quantum probabilities" and "quantum logic". These simply are not intelligible in terms of what is classically called probabilities and logic. This manifests strikingly that the *general* epistemological consequences of the quantum mechanical formalism, if elaborated, modify the structure of our classical representations of probabilities and of logic, the two most basic and worked out representations of domains of our everyday thinking and acting. Indeed, when the universal representation of the very first stage of our conceptualization processes, drawn by generalization from quantum mechanics, is injected into classical probabilities and classical logic, they undergo a sort of spectral decomposition; and this places into evidence that, far down beneath language, probabilistic and logical conceptualization merge

into one unified probabilistic-logical structure. This circumstance entails deep conceptual clarifications as well as corresponding formal modifications. No other theory of a domain of reality, not even Einstein's relativity, has ever triggered an outflow of a comparable scope, so deep-set and so powerfully innovating.

This, however, though variously felt and much discussed and analyzed for more than 70 years, often with remarkable penetration, nevertheless is still very far from being fully known and understood. The general epistemological implications of quantum mechanics are still cryptic, even for most physicists and even for many who currently manipulate the formalism, often in a masterly manner. *A fortiori*, quantum mechanics is very superficially and feebly connected to the development of other new scientific approaches. This is a *huge* lacuna. It hinders a free, rapid, and maximal development of the revolution of the basic concept of object, implicitly started by quantum mechanics, but the pressure of which manifests itself also in biology, systemics, information theory, etc. Thus it also inhibits the perception and full elaboration of the consequences of this revolution upon logic and probabilities that guide our everyday thinking. Thereby it obstructs the now-*possible* radical progress in our knowledge of our manner of producing knowledge. Which furthermore delays a now-possible dramatic improvement of an explicit and deliberate domination of our epistemological behaviour, and thus also of our actions.

One of the main aims of this book is to fill this lacuna.

This aim joins with a still larger one, which stems from the postulate that *any* big theory of a domain of reality fixes in the concepts and the structures defined by it, certain essential features of the epistemological processes by which the human mind generates representations of what we call reality. But, as happens in the special case of quantum mechanics, these features tend always to remain more or less implicit in the descriptional substance that has incorporated them, which entails that their universal value remains unused. *A fortiori*, the different epistemological innovations that accompany different scientific approaches, in general remain unreferred to one another, which blocks the emergence of an integration.

So, for instance, the theory of information obviously involves a certain epistemological universality. Any "transmission of knowledge"—even if it is a natural, non-intentional process of just the *acquisition* of knowledge, or a scientifically normed process of measurement, i.e., of deliberately organized transmission of data from an object of study to the mind of an investigator, etc.—can be cast in the canonical mould of the theory of information, according to which there always exists a source of "information" that issues "messages", a "channel" for the transmission of information which can alter

in various ways the messages sent through it, and a "receiver" that attempts to restore the original message out of the received one. This remarkable generality entails a tendency to apply the informational representation (initially conceived for the engineering of communication devices) to the most diverse domains, in biology, in the theory of physical measurements, in linguistics, and so on. It would therefore certainly be fruitful to explicate thoroughly the general epistemological presuppositions of the information-theoretical formalism and to confront them systematically with those involved in other approaches. The theory of quantum mechanical measurements clearly offers an opportunity for a particularly interesting confrontation. Indeed, this theory distills the essence of fundamental quantum mechanics *and* quite essentially addresses an informational problem. Nevertheless, the *formalism of the quantum mechanical measurement theory possesses certain formal features that are essentially* `different` *from those of the informational formalism*. It would by interesting to explore what facts, assumptions, and methodological choices underlie this unexpected difference. While it might produce a deeper understanding of the, so central, general concept of "information", such an investgation could perhaps furthermore lead to a reformulation of the theory of information in terms of Hilbert mathematics,[2] which probably would be a formulation much deeper, more precise and general than the present one. In turn, a re-expression in terms of Hilbert mathematics of the theorems from information theory (especially the second theorem of Shannon) could draw the famous question of hidden parameters into an organized and mathematical framework; additionally it should foster important clarifications concerning the concept of physical superposition as well as throw further light on the concept of "object".

Considerations of a similar nature could be advanced for several other modern disciplines, in particular for the various computational approaches, for molecular and genetic biology and, quite specially, the modern cognitivistic approaches.

But the preceding considerations suffice already to convey the following conclusion:

> What is lacking in order to improve our knowledge and control of the modes available for the generation and communication of knowledge, thoroughly and rapidly and with precision and detail, is a systematic research within the mutually isolated special languages belonging to all the major modern scientific disciplines, of the epistemological essence inherent in every one of them, and a systematic cross-referencing of the explicated results.

[2] I do not write Hilbert *vectors*, because evidently a principle of superposition permitting a pertinent use of vector spaces does *not* hold for any transmission of information

Indeed, in its own sphere of representation, each approach traces a certain specific direction of conceptualization. But what are the "angles" between these directions? What are the contents of their "projections" on each other? And what new *metawhole* can pertinently be constructed from such comparisons?

This conclusion and the questions that surround it lead us to formulate the following aim: from the most profound and best-performing modern scientific disciplines, to induce an explicit and formalized *method of conceptualization*, basic enough to:

(a) encompass in a unifying and optimizing structure the main specific procedures for generating knowledge employed in all these disciplines;

(b) assign within this structure a definite location for each one of these procedures;

(c) generate comparability among these specific procedures and among their results.

This, I hold, is an important aim. A better understanding of it can be gained from the following specifications:

From the start, what is desired is the construction of a *method*, not of a neutral description of the processes of conceptualization such as they may spontaneously emerge. In fact, a perfectly neutral description would not be a possible goal, and, even if it were, it would be devoid of any definite and immediate pragmatic interest.

As for the requirement of a "formalized" method, it can be explained as follows: Any methodology involves its subjection to some system of aims. A minimal finality that seems imperative when a method of conceptualization is planned, is to offer general algorithms for excluding the emergence of false problems and paradoxes, while insuring rapid progressions, without hindering thereby a fully free exercise of the peculiar curiosities of the conceptualizing mind. The foregoing, if at all achievable, can however be realized only by an *extraction* of the method from the current language. The most radical extraction would result from the definition of a "formal" method where exclusively nonverbal symbols, well-formed sequences of such symbols, and transformation laws involving all of these, are put to work. But this is `not` the aim proposed here, because significance, semantics, is primordially essential when one conceptualizes. So, instead of "formal", we use the term "formalized", which implies that *something to be formalized has been formed before,* independently (as, for instance, is the case for a mathematized theory of a domain of physical reality, say, the Faraday-Ampère-Biot-Savart-Laplace-etc. system of descriptions, which Maxwell then re-expressed

in mathematical terms).[3] Accordingly, in our case the first stage should consist of the explicit construction of a general system of posits, definitions, and procedures, constituting a self-consistent network of routes for directed and safe conceptualization, inaccessible to the innumerable and unpredictable obstacles inherent in the tortuous paths of conceptualization which each one of us hews for himself in accordance with his own ability and way of thinking induced in his mind by the usual language. Of course, a system of this kind has to be expressed in words. Nonetheless, as a *system*, it is a self-consistent whole, already extracted from current language, already endowed with a certain degree of imperviousness with respect to an uncontrolled inflow of harmonics of significance triggered by words depending on the density of the *structure* the system has been endowed with.

The second stage, then, should consist of a `formalization` of the methodological system constructed in the first stage (or in several formal-

[3]From one contribution to this volume to the next, the reader will notice oscillations between the terms "formalized" and "formal". In this connection, in a recent letter, Hervé Barreau wrote to me:

" ... As for the essence, we are in agreement, since for all of us, and especially for you and me, it is quite obvious that the sort of epistemology we want to construct presupposes that we conserve the (often very complex) semantic of the involved terms, upon which we shall try to impose constraints of "form" in order to stabilize invariants of meaning which in the usual language in general get lost. Initially, for me, "formal epistemology" meant precisely this submission to formal constraints of a basic *semantic* which has to be kept. What rejected me in the expression "formalized epistemology", was that it might be understood accordingly to the opposition between "formal logic" and "formalized logic". The formal logic, of which the classical example is Aristotle's logic, conserves in it a basic semantic which permits to produce counter-examples in order to exclude a possibility that is allowed by the criteria of pure form: for instance, when he wants to exclude certain syllogistic modes relative to some given "figure", Aristotle gives proofs by *ecthesis*, that is, by specification of a counter-exemple (this procedure is still current, in particular, in modal logic). While on the contrary, formalized logic makes abstraction of any content. This is not the case in Frege's first presentation of his logic, but this is the case in the axiomatization of his logic. This is equally the case in Wittgenstein's "semantic tables" where the only "semantic" notations kept (namely "true" and "false") finally are indifferent since the tautologies, the formal laws, are valid independently of the truth-values of the involved statements. So the formalized logic concerns exclusively statements and not propositions (statements asserted to be true or false). In a similar way, for the formalists mathematics is a formalized knowledge that is independent of the semantic content, not only a formal science. This is the distinction which I had learned in the school books of logic and mathematics. But the explanation you gave last Thursday assign an opposite significance to this opposition, and it raised no objections ... ."

This quotation shows clearly that (a) throughout this volume it is admitted by all the contributors that the semantic contents are an essential element in the researched epistemology; (b) those who use the word "formalized" refer to the paradigmatic example of a mathematical theory of a domain of physical facts, while those who make use of the term "formal" refer implicitly to certain traditional expressions concerning logic (though nowadays "formal logic" is considered to deal with purely syntactical systems).

izations), mathematical or not, the initial outline being kept present as a nourishing soil. Thereby, without loss of nuances, the precision and efficiency of the processes of general conceptualization achievable by use of the method would become comparable to those which logic has attained for the particular purpose of combining and transporting truth-values of propositions, or to those which a mathematical theory of a domain of physical reality insures for the representation of physical phenomena, under constraints of inter-subjective consensus and predictability.

> *A methodology of the kind specified above is what we call* `a formalized epistemology`.

By the nature of its aim, a formalized epistemology should emerge much more general and, nevertheless, by far *less abstract* than the representations built in metamathematics or in the logical theories of hierarchical languages.

The project sketched above should not be mistaken for a crossdisciplinary or a multidisciplinary project. The latter projects are designed to offer to nonspecialists access to *information*, to results obtained inside specialized disciplines, as well as a certain understanding of these results; by contrast a method of conceptualization should equip anyone with an *instrument* for conceptualizing in whatever domain and direction he or she might choose. Our planned method should furthermore not be assimilated either with any approach belonging to the modern cognitive sciences, which try to establish as neutrally as possible descriptions of how the human body-and-mind function spontaneously when knowledge is generated; whereas a method of conceptualization should establish what conceptual-operational deliberate procedures have to be applied in order to represent and to achieve processes of generation of knowledge optimized according to definite aims.

It seems however clear that a method of conceptualization of the sort we have defined would share some features with the crossdisciplinary or multidisciplinary approaches and with the cognitive sciences (as well as, furthermore, with a theory of a domain of facts).

Now, is a formalized epistemology possible at all? The hopeful purpose of this volume is to bring about agreement on a positive answer.

The volume is organized in three parts.

The first part offers various perspectives on the aim proposed in this Introduction: its historical roots, its present conceptual environment, estimations of its possible content and of its pragmatic value, the difficulties entailed by it, and its *a priori* chances to succeed. These preliminaries seem necessary in order to deepen the intuition for what is desired and to create a background for the constructive attempts we will propose.

The second part contains three constructive approaches which form the core of the present volume.

The third part features critical-constructive explorations concerning the present stage of knowledge in several different domains of investigation (philosophy of time, physics, logic, mathematics, computation, linguistics, and complexity), each one more or less explicitly related to the concept of a formalized epistemology. In this manner, around the constructive approaches from the second part, new ground is broken for future positive developments.

The whole, I think, will offer a rather complete account of the synthesizing dynamics conducted within the CeSEF.

Mioara Mugur-Schächter

IMPORTANT NOTE

For the reasons indicated in the above Introduction, please read "formalized epistemology" instead of "formal epistemology" wherever the latter term appears in Chapters 1, 3, 5, 6, and 8. We much apologize to our readers for this unavoidable inconvenience.