THESES TOWARDS A NEW NATURAL PHILOSOPHY

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ABSTRACT

In this paper I address some philosophical questions regarding the impact quantum mechanics has in the classical conceptions about reality and knowledge. I stress that onto-gnosiological realism still is an option to the issues regarding the relationship between knowledge and reality. Rejecting some radical aspects of Copenhagen interpretation of quantum formalism, I emphasize the advantages of de Broglie's realistic and causal model. To finish with, I discuss the limits of the Cartesian concept of matter and the split between matter and mind.

Keywords: Realism, Quantum Mechanics, Gnosiology, Natural Philosophy.

Philosophers dramatically misunderstand the sense of their task when they embrace a kind of scholasticism, writing entire books about the opinions of other distinguished philosophers instead of talking about the things themselves. Unfortunately, this has become a widespread situation since philosophy was confused with the history of philosophy. This kind of category-mistake was first committed by Hegel. After him, in the late 19th century, with Dilthey and others, it degenerated into a historicism of sceptical and relativistic guises. However, before philosophy came to this regrettable situation, philosophers like Descartes, Leibniz, Kant –or even Helmholtz, to mention only a case of a nineteen-century philosopher of non-Hegelian extraction– were concerned with the formidable task of producing an organized and sound understanding of reality. They were not worried about erudite questions concerning the history of philosophy, nor did they come to their own opinions reading the philosophers of the past. The lack of historical erudition was a common feature of thinkers and natural philosophers like Bruno, Galileo, Descartes, Newton or even Kant. Instead, they were fully aware of the scientific atmosphere of their time. Indeed, it was the accuracy of their answers to problems concerning our knowledge of reality that gave them the label of classical scientific thinkers and philosophers.

Surely, I am not making a case for ignorance and lack of relevant information. I am only suggesting that the kind of dialogue we should have with other philosophers is one which proves capable of improving our knowledge of reality – that is: a dialogue not for the sake of interpretation, but for the sake of truth.

This productive attitude towards the intellectual legacy of philosophy is particularly appropriate in our times. In fact, we are experiencing the aftermath of an intense intellectual turmoil, which has taken place in the 20th century and has shaken the very foundations of the classical image of reality that three hundreds of continuous scientific developments had given us. The turmoil started in the first three decades of the last century. It was centred on the conception –or a lack thereof– of reality that recent advancements in physics and cosmology were suggesting. This debate about the ideas that new physics and cosmology were dramatically changing and reshaping engaged outstanding researchers like Planck, Bohr, Heisenberg, Einstein, Schrödinger, de Broglie, Bohm, de Sitter, Gamow, Hoyle, and so many others. The hard work they did was not related to physics or cosmology in a narrow sense. It was too deep and far-reaching to be locked-up in a particular science. In fact, it spread to domains like gnosiology and ontology, i.e., it entailed a revision –or at least a reappraisal– of such basic ideas as our general conceptions of reality, the material Universe and knowledge.

As a matter of fact, regarding our scientific knowledge and technical domination of nature, the 20th century was a time of astonishing progress. For the first time since the Greek split between *theoria* and *techne,* the capabilities for a technical transformation were systematically linked with science, sometimes benefiting from its achievements, at other times promoting them. These achievements embraced the smallest as well as the largest structures of nature – they went from the atomic and subatomic structures to stars, galaxies and the formation of the cosmos. Two new theoretical constructions guided this amazing progress: quantum mechanics, on the one hand, and, on the other, the complex and not-so-straightforward conglomerate of observations, hypotheses and hard speculations that extended from Einstein's *Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie,* published early in 1917, to the Big Bang theory and the standard cosmological models of today.

Alongside this extraordinary growth, a baffling situation emerged: our classical image of nature was becoming more and more blurred but, despite the enormous work of the fathers of quantum mechanics and modern cosmology, nothing very clear, well defined and uncontroversial was put in its place. This is tantamount to saying that modern physics and cosmology have put us in the middle of a crisis. Physics, particularly quantum mechanics in the prevailing "Copenhagen Interpretation" by Bohr and his associates, suggested a non-causal and rather indeterminist behaviour of atomic and subatomic entities, proposing a puzzling description of the deepest structures of matter. In fact, quantum jumps (assumed by Bohr since 1913, when he was in Rutherford's laboratory at Manchester), wave-particle duality and the complementarity-principle (Bohr's way out of the conundrum of the double-slit experiment), the collapse of the wave-function (attributing a kind of creative power to measuring acts), and the new interpretation of quantum probabilities (which was Bohr's appropriation of Schrödinger's equation), lead to a non-causal, rather indeterminist and mind-dependent conception of reality. The question concerning Bohr's interpretation of quantum mechanics, especially his considerations about the principle of complementarity, was not meant to bring forward a new understanding of the atomic and subatomic world, but to signal some unbreakable limits in the human efforts to understand nature. With quantum mechanics, we had eventually a mathematical formalism with extraordinary predictive capabilities but no clear interpretation of the *physical meaning* of these very formulae we managed to put together so well. Bohr himself wrote on this subject several times, so that his interpretation sounds as a farewell to a full understanding of nature as such. On the other hand, modern cosmology, based both on Einstein's equations of general relativity (without the cosmological constant) and on the interpretation of the galactic red-shift, discovered by Hubble, as a Doppler-effect, led to the idea of an expanding universe that at earlier times was much hotter and denser than today. Tracing this expansion backwards and supposing it was permanent, cosmologists constructed the hazardous hypothesis of a definite time in the past when the universe would have been infinitely dense. This time, the genuine "beginning" of the Universe, as we are told in a somewhat biblical fashion, has come to be called the "Big Bang", ironically the very same name Hoyle used for mocking it.

In a word, despite the independent paths they have treaded during the 20th century, quantum mechanics in "Kopenhagener Geist" and Bing Bang cosmology have together given an indelible sense of strangeness both to physical matter and to the Universe as a whole. Regarding cosmology, with the guiding hypothesis of an expansion, both the old cosmogonist ways of thinking and the idea of the creation of the material Universe were revitalized. Despite new questions, like those pertaining to the overall geometry of the Universe (if it is flat or otherwise) as determined by the value of the Omega Cosmological Parameter, we are now facing some old-fashioned problems like the alleged beginning and end of the Universe, its duration, its finite or infinite magnitude in space-time, and so on – problems that remind us of some metaphysical queries of the past and also of the lessons Kant gave us about it in the Antinomies of his *Kritik der reinen Vernunft*. In addition to this, we are facing the perplexing situation of a singularity to which the laws of physics no longer apply, so that the very beginning of the Universe (earlier then the so-called "Planck epoch"), postulated by cosmology, is no longer a matter of physics but of some inexplicable processes that took place nobody knows how and why. This puzzling singularity is, then, the point where *physis* comes to an end and conceals both its nature and origin. On the other hand, the classical conception of physical matter as something fully determined and submitted to necessary causal laws has been strongly challenged by particle physics. Furthermore, with the complementarity-principle and the putative impossibility of attributing determined states to a system before measuring operations, some strong general ontological conceptions about what a being is and about the relationship between reality and consciousness (knowledge) were challenged; we do not know if the principle according to which every being is necessarily fully determined in all its states is actually a good principle to characterize reality or, on the contrary, an oversimplification based on the apparent constancy and completion of objects of our macroscopic perceptual world; we also do not know if we can retain a mind-independent, non-idealist conception of reality. As a result, we are comfortable neither epistemologically nor metaphysically or even scientifically, given the rather confused image we now have of the Universe we live in. As everyone can see, more than the right answers, we are in need of the right questions, because we do not know if contemporary trends in physics and cosmology are on the good paths at all. In face of so many conundrums and seemingly dead ends (particularly in the standard cosmological model), we do not need more physics and more cosmology conducted in the usual ways, but, instead of this, we need a lot of *critical discussions* about the very foundations of physics and cosmology and possibly some really new physics and some really new cosmology in the ways these critical discussions will pave for us. In a word: we need to turn back to the open space of philosophy.

For this is, in fact, a matter of philosophical inquiry, a problem for a natural philosopher, not as somebody who reads (all) but as someone who (incompletely) responds to the huge problems reality addresses to us. A *gigantomachia peri tes ousias,* i.e., a battle of giants concerning what is, as Plato wrote: this is what philosophy is really about.

So we will address the following questions:

In what relationship does knowledge stand to reality? Is reality conceptually independent of knowledge?

What is it to know? How can we describe the chain of cognitive operations that must take place, so that we can go from (the bare existence of) *x* to the (cognitive) situation *x-is-know*? Do classical conceptions about knowledge still hold?

And what is a being after all, an *ens,* to take up again the Latin jargon of the old metaphysics and ontology? Can we conceive a being which is not fully determined regarding all possible predicates that can be attributed to it? Does causality hold universally if there is something like non-complete determination?

Finally, what is *physis*? Is *physis* fully understandable through the classical Galileo-Cartesian concepts of physics? And if not, what else do we need? In light of particle physics, can we have a cosmogenetic conception for *physis* as a whole?

1 – Reality and knowledge: in search of a conceptual clarification

Reality is prior to knowledge. Yet, the traditional way of defining this priority (*viz*., reality is what it is regardless of being known or not) is not entirely accurate.

The word "prior" above means a relation determined by the semantic content of concepts alone, not a temporal relation or a genetic one between the things referred to by the concepts. So the proposition does not mean that reality comes before knowledge or that knowledge springs from reality. It means that, in order to define the concept of knowledge, we must presuppose the concept of reality and attribute some content to it that is independent of any relationship to knowledge. So we must define precisely what this independent content is.

To begin with, let us say something about the priority-relation that holds between reality and knowledge. It has several meanings that are interrelated. Nevertheless, they do not imply each other. Going from the weakest to the stronger, they are the following:

(i) *A particular sense of aboutness*. Like perceiving, imagining, supposing, and so on, knowing is always about something, i.e., it has a content we can describe. Unlike the other forms, however, if, say, it is true that *p* is known (for instance, if it is known that the Earth is a planet of the Solar System), then *p* is the case, i.e., "*p*" can be asserted as a true proposition. The same does not happen in cases like imagining that *p,* supposing that *p*, thinking, or even perceiving, because from the truth of "I suppose that *p*" it does not follow that *p* must be the case and that "*p*" can be asserted as true. Indeed, "I suppose that *p*" can be true and "*p*" false, or inversely. If I suppose that Scott was the first man to arrive at the South Pole, my supposition is wrong, but it is nevertheless true that I have such a supposition. On the contrary, if I say that I *know* Scott was the first man to arrive to the South Pole, the falsity of the assertion implies that it is not the case that I have authentic knowledge. So, unlike the other cases (supposing, imagining, thinking, and so on), I cannot say here that "*p*" is false and that "I know that *p*" is true: if *p* is false I do not have any knowledge at all.

So only what is the case qualifies as an actual or possible object of knowledge, and, therefore, knowledge is always about what is. For instance, we cannot know anything about the Olympic gods because they do not exist. However, the cultural facts of ancient Greece are real, and we can know them, namely the stories about fictional characters like Zeus or Poseidon. As a general rule, we must say: if it is true that *p* is known, then *p* is the case (we cannot say yet what the criteria of true knowledge are). The negative judgments (e.g., "Earth is not a star") express no cognizance of unrealities as such, but a cognition that it is the case that something is not true (*viz.,* that "Earth is a star" is a false proposition). The sum of all that is the case is what we call here "reality" in a wide sense, including what is actual, possible, probable, and so on. Reality is what authentic knowledge asserts, even when this true knowledge is not about an actuality but, say, a possibility, a probability, or something else (if it is true that *p* is probable, then it is the case that this probability is a "real" state of affairs). Being real is, then, a necessary condition for being known. On the contrary, if one thing or state of affairs is real, it does not immediately follow that it is or can be known. So being-real is not a sufficient condition for being-known.

(ii) *Irreducibility*. Knowledge is about reality, but reality is irreducible to knowledge. This does not simply mean that there are always more aspects and domains of reality to be known. Such an assertion would be a matter of common sense and an everlasting but trivial truth. This does not mean either that there are absolute limits to knowledge. That would be a very controversial gnosiological thesis. The proposition that states here the irreducibility of reality to knowledge means that what is effectively known is always conceptually understandable and explainable in another theoretical framework. It states, then, that there is no ultimate theory that captures reality –a "theory mirror", so to speak– because there is no "true image of reality" as such, but only reality under a certain description in a determinate conceptual framework. For instance, gravitation phenomena can be conceptually grasped and explained in terms of concepts like force, action at a distance, absolute space, or in terms of space-time curvature, matter-energy density, tensors, and so on. The conceptual universes are pretty different, but the underlying phenomena are very much the same, with a somewhat changing degree of observational accuracy determined by the conceptual and mathematical sophistication of each theory.

So we must distinguish between the conceptual and (if any) mathematical framework of a theory, on the one hand, and the underlying material nucleus, on the other hand, i.e., the material kernel of what the theory is about. We cannot say: “the underlying material *facts*”, because a fact is almost always the function of a theory – it is already a reality under a determinate description. So, for a theory like the ancient Atomism, the falling-down of atoms in void was a fact. Atomists could even “see” it in phenomena like the fall of bodies on Earth. Nevertheless, for Newton’s conception of an absolute, homogeneous physical space, there are no such facts as the falling-down of bodies: the facts are, instead of this, the uniform and accelerated motions due to the action of forces, namely the gravitational force, for the case of those fall-phenomena on Earth that experience immediately shows to us. Thus our description of the facts varies –or simply the facts vary– as the theories that imply them change.

So, if we look at reality as irreducible to any form of conceptual thinking, no matter how successful it can be, we must realize that there is no privileged form of access to it. The thesis that perception, as a supposed pre-conceptual, pre-theoretical experience, would be the original form for the presentation of reality –a thesis put forward, in phenomenology, by Merleau-Ponty and, to a certain extent, by Husserl himself– must be denounced as an illusion. This is so, firstly, because perception is already a conceptual grasping of reality, and, secondly, because perception, as a presentation of nature, entails a kind of “folk-physics”, so to speak, as it suggests a conception of physical reality in terms of sensible qualities, the four elements, material bodies and forces, psychic causes for movements, and a lot of oppositions like day-night, earth-sky, plenum-void, etc. Perception is not an original or trustworthy, but an anthropological, culturally laden, conceptual and sensible presentation of reality: it has no special rights, neither regarding originality nor regarding truth. Considering reality by itself amounts to taking notice of certain recurrent regularities and patterns of organization as a basis for conceptual formation. For instance, some regular kinetic phenomena, like the behaviour of bodies on Earth’s surface, give the empirical basis for different conceptual understandings and theoretical constructions, like Aristotle’s theory of natural places or Newton’s gravitation law, which are applicable to the same patterns of earthly kinetic regularity.

If, on the other hand, we look to the multiple forms of theoretical thinking, we must acknowledge its relativity, but not embrace relativism. Actually, theories are not equivalent, and the election of one is not a matter of free choice. There are constraints. The refusal of an “ultimate theory” (the irreducibility-thesis) inhibits us from talking about a progressive approximation to the “true image” of reality. Nevertheless, this is not tantamount to accepting Kuhnian conceptions about the discontinuities of paradigm shifts and their incommensurability, or to talk about the supposed loss of theoretical explanatory power in the substitution of one theory for another, as pointed out by Laudan, while discussing birefringence in face of Huygens’ and Newton’s optical conceptions. There is progress in the succession of theories: that Newton’s gravitational theory is more accurate than Aristotle’s theory of natural places is a blatantly truth. Furthermore, partial losses of explicative power are compensated in the long run, as in the case of the return to an explanation of birefringence in terms of the wave-theory of light in the 19th century. In general, theories fit or do not fit a number of phenomena and regularities already known. Theories have or do not have the capability of predicting new phenomena. Theories can grow or not, and are able, or not, to assimilate other theories. These are just some of the constraints determining the election of one theory.

We started by saying that reality is what true propositions assert. We now reach a deeper understanding. Reality is what true propositions of competing theories are about, i.e., the underlying phenomena and regularities. Surely, phenomena are only expressible in a conceptual framework (as “facts of the theory”); nevertheless, phenomena are always able to say “no” to theories and explanations. In a rough sketch, we could say that propositions “A < B” and “B > A” express the same metric state of affairs between A and B. The state of affairs by itself is not expressible without the point of view of one or the other propositions. Still, it makes good sense to say that the state of affairs is none of them, but the –unique– thing the two propositions are about. The relation between reality and theoretical thinking is the same, with the qualification that some theories are better fitted than others both to express and to explain phenomena.

(iii) *Non-substitutability*. Every attempt to ascribe to knowledge an object that is immanent to it will misconstrue and destroy the very concept of knowledge.

In order to show this, let us considerer two classical cases that are instructive to several contemporary conceptions. British empiricism explained knowledge as a set of "operations of the mind" over its own sense-data, by means of which an indirect cognizance of an external reality was obtained, as John Locke put it. These directions in gnosiological thinking have led, with Hume and Berkeley, to a sceptical doubt about "external" reality and even to the denial of such a thing as a material, mind-independent world. As a matter of fact, when Berkeley put forward his thesis of immaterialism he was only extracting a radical consequence from the original presuppositions of Locke's empiricism: if knowledge is constructed as a set of operations by the mind over sense-data, the very concept of a mind-independent, external reality will be pointless and fruitless. So when Berkeley said famously that a Law of Nature was not a description of some processes taking place in a material universe, but simply a rule for predicting a set of future sensations given a particular set of present sensations, he was just taking the final step in full accordance with empiricist gnosiology – the total substitution of objective reality by predictions about our own future subjective observations as the very object of knowledge. Maybe not so surprisingly, some formulations by Heisenberg about the kind of knowledge we have in quantum mechanics are not very far from this epistemic conception. As a matter of fact, since the very beginning, Heisenberg affirmed that his matrix mechanics was no more than an algorithm for correlating results of experimental observations and making new predictions on that basis. That is to say that his theory was unable to give some glimpses beyond the realm of our empirical observations – it was not a depiction of atomic reality. Surely, for Heisenberg and contrary to Berkeley's standpoint, there is a reality underlying sensible objects (empirical objects). But –he insisted– statements about the physical world are statements about what we can experimentally perceive and verify, and so, science has no good grips beyond this empirical level. These epistemic conceptions were so deeply rooted in Heisenberg's mind that he reaffirmed them in 1962, long after his controversy with Schrödinger's wave mechanics and the necessity he had of justifying the artificiality (from a physical point of view) of his matrix mechanics. Actually, in a text based on his Gifford-lectures, called *Physik und Philosophie,* he stated once more that scientific statements in quantum mechanics were not about an underlying reality, but about our own knowledge, i.e. about predictions over probabilities of future observational states.

The Kantian distinction between appearance and thing-in-itself was an attempt to overcome the sceptical trends stemming from the empiricist stance. The assumption of a mind-independent reality was preserved by defending the possibility of thinking (not of cognizing) a realm of things in themselves, while, on the other hand, the empiricist concept of sense-data was retained and transformed into the concept of an "appearing object" (*erscheinender Gegenstand*) for knowledge, i.e., something that is not a state of mind, a simple sensation (it is already an *object* – *Gegenstand*), but something that, nevertheless, has an intuition and concept-dependent objectivity (it is still an *appearance* to the mind – an *Erscheinung*). However, this Kantian conceptual distinction between a double way of considering things –as they are in themselves and as they appear to us– boils down to the following dilemma: either our cognition of appearances leads to the cognition of things as they are in themselves, so that the distinction cancels itself out, or our cognition of appearances does not lead to a cognizance of things as they are, so that the cognition we have is a fake presentation of reality. There is no way out of this dilemma. The very opposition between reality as it is as such and as it appears to us must be overthrown, not to mention that we do not fully understand what is really meant by expressions like "as such" and "to us". A lot of conceptual work is in need here.

So empiricism as well as Kantian gnosiology are classical cases of a construction of the object of knowledge as something immanent to knowledge itself. The concept of immanence we use here does not signify sheer interiority. As a matter of fact, while sensations are internal in a psychological sense, Kantian phenomena are typically external objects in space and time (not considering another group of phenomena Kant calls "objects of the inner sense", i.e., states of mind, *Vorstellungen*). Nevertheless, sense-data and phenomena (more precisely: appearing objects) are cases of immanent objects in the sense of something that has no independent existence outside its relationship to knowledge itself. And this is just the point. If the general purpose of knowledge is only the prediction of subjective observational states, the concept of reality does not need a precise definition and can be characterized as the unknown cause of sensations in the knowing subject. This unknown cause can be a material universe as well as God's will or something else, as Berkeley emphasized (Berkeley himself supported the radical hypothesis of God's direct action without the mediation of a –for him superfluous– material universe). But this entails that the concepts of science lose their foundation, because no relationship can be established between them and the ontological content of reality as such. As a matter of fact, we use concepts like space, body, mass, acceleration, field, and so on, to pick out and bind sense-data. But we can no longer trace any connection between the content of these concepts and the unknown content of the "outside" reality. This is a clear admission that all our concepts have no basis at all and, thus, this counts as a self-destruction of the objectivity of knowledge itself. By the same token, the Kantian distinction between a world for us and a realm of things-in-themselves refers epistemic procedures back to the forms of intuition and the concepts of the knowing subject without any justification for the fact that he uses precisely these forms and these concepts and not any other forms or concepts. For instance, the forms of our intuition impose the presentation of a spatiotemporal world. But why do we have these forms and not others? Why must a spatiotemporal world exist (for us)? The Kantian answer (*viz.,* because these are precisely the a priori forms of our faculty of intuition) is not good enough, for we would like to know why we have these forms instead of others and, in the end, if these forms are homogeneous or, at least, a good approximation to the paramount reality, i.e., the realm of things as they are when considered in themselves.

So we cannot construct the concept of knowledge avoiding a reference to reality as such. If the object of knowledge is not a reality independent of the knowing operations, but just our observational future states or a (minor) object entirely dependent on our faculties of cognition –an object naively defined as being only "for us"–, we will contravene the normal sense of the concept of knowledge, which amounts to an intentional grasping of something that precedes the very acts that apprehend it, or, to say it somewhat more technically, to something that has not those very acts of cognition as a condition for the possibility of its own existence. As a result, the concept of reality cannot be replaced by another in the definition of knowledge. If we say that knowledge is about predictions of observational states or about objects entirely constructed by our subjective forms of apprehension and thought, we will lose the very objectivity of knowledge, because we can no longer trace any relation between the concepts we use (like space, time, mass, force, field, etc.) and the very reality we have excluded from the outset from the definition of knowledge.

Thus we get a final characterization of the way reality is prior to knowledge: the fundamental concepts of knowledge must give a sound presentation of reality as something whose existence is independent from the very operations by means of which it is known. That is to say: the fundamental concepts we use must give rise to a "realistic" interpretation. In the present state of our knowledge, our fundamental concepts have imposed an interpretation of reality as a physical realm, and this physical realm as a domain of events understandable in terms of concepts such as mass, field, particle, wave, and so on. Yet this is not the final word on these matters. In accordance with what has been said, we reject the idea, so cherished by Schlick and Reichenbach, that physical knowledge is simply a matter of coordination (*Zuordnung*) between mathematical equations and sense-data. Fundamental concepts must lead to a coherent realistic representation, or just to a representation of a realm of physical reality, if we take for granted the assumption we do not want to discuss that the basic form of reality is *physical* reality.

And so are we carried to the question: what is *physis*?

But before that we must say something else about knowledge itself.

2 – Reappraising realism: what is really in question in quantum physics?

Bearing in mind what we said above, let us establish some important conclusions.

First, if we are right, knowledge is bound to strive for the following goals:

1. If, going away from the sterile womb of semantics, we associate to the propositional attitude report "I know that…" the idea of some procedure for obtaining knowledge, be it experimental or otherwise, so that the clause "I know that…" refers the state of knowing to a certain previous cognitive activity culminating in the verification that *p* is the case, then we can state what we will call from now on the "objectivity rule" ("OR" for short):

> **OR:** If I know that *p, p* is the case *simpliciter* and not just under the conditions it has been known, so that *p* can be released from the particular conditions under which it has been known and asserted as true regardless of any verification method.

If the objectivity rule applies to the content of an assertion, e.g., "The average distance between the Sun and the Earth is 149 million kilometres", this signifies that the physical state of affairs referred to by the statement is equally the same for a multiplicity of different verification methods, so that it is independent of any disturbance a chosen measuring device could impinge on it. That is to say that an objectified assertion talks about some objective feature of reality invariant despite a change in verification method, i.e., it talks about what simply is the case, not about the results of an interaction between a physical system and a measuring device or about the proper states of the measuring apparatus.

2. We have talked above about irreducibility as the second sense of priority. Let us extract one important lesson from that.

Instead of the common but somewhat naïve conception that there are facts we can simply collect, we state that it is not possible to collect immediately facts from nature, but that they must be constituted through conceptual and methodological procedures. For instance, the fact of acceleration in Newton's mechanics supposes the concepts of absolute space and time, as well as the mathematical method of fluxions, so that the concepts of applied force and inertial mass can subsequently intervene as explanatory concepts. Thus we must say that knowledge is not simply a matter of putting facts under explanatory concepts. The very facts we explain point back to constitutive concepts. These are not bound to direct empirical justification. They are kinds of postulates of empirical knowledge. Hence, there are several strata of disagreement between theories. They can disagree at the level of the explanation of facts, i.e., at the level of explanatory concepts (for instance, Doppler-effect versus tired-light as an overall explanation for the galactic red-shift), or they can disagree about the very facts they are facing, that is, at the level of the constitutive concepts and the mathematics associated with them. A clear example is the understanding of light *as* a wave or *as* a beam of particles (no need to say that the mathematical properties of waves and particles are pretty different). Another clear example is Thomson's model and Rutherford-Bohr's model as conflicting depictions of the inner structure of the atom. Whenever we arrive at a primary characterization of the nature and structure of an entity, we use models of intelligibility that are constitutive concepts. Thus we go from phenomena to facts by means of constitutive concepts, and from facts to explicative theories by means of explanatory concepts, so that we can state a kind of hierarchy rule (HR) applying to the several layers of concept formation:

> **HR:** Constitutive concepts give structure to phenomena, converting them into facts; explanatory concepts connect facts to other facts in dependence chains; a change in constitutive concepts can change facts and often leads to the discovery of new realm of phenomena; a change in explanatory concepts leads only to a new explanatory hypothesis.

Explanatory concepts enter explicative theories that either fit or do not fit the facts already recognized; on the other hand, the justification of constitutive concepts lies more deeply in its aptitude to give intelligible structure to phenomena, to disclose new realms of phenomena and to establish new kinds of facts.

3. Finally, let us stress that, in accordance with the third sense of priority, to give a representation of an observer-independent reality is not to depict reality as it is without knowledge –this is a self-contradictory idea– nor to subtract the impact knowledge has on reality –this will bring us back to the point of departure–, but to accept what we will call from now on the "objective reasoning rule" (ORR). This rule allows us to think in terms of an objective reality that follows its own development independently of the circumstance of being proved by a measuring device or not. We can state it as follows:

> **ORR:** The state of any physical system is self-determined by its own laws of development; two systems acquire new states at the moment of their interaction and pursue after that separated world lines; reasoning can anticipate what will be the future state of a system relying solely on its past-story, so that our measuring devices do not create the states of physical systems, but merely prove an observer-independent reality.

This condition used to be articulated as a demand for both causality and determinism. In fact, causal thinking is a way of thinking "as if we were not there", so to speak: we simply figure out what is happening. So causal thinking is intimately connected to the idea of an objective realm governed by its own laws. In addition, the separation of physical systems implies locality and the refusal of connections between events faster than any velocity of signal transmission (although we begin to suspect that time-like intervals of space-time light cones are no limits at all for signal transmission –there are experimental grounds to admit superluminal velocity, i.e., space-like intervals *with* causal connection–, no instantaneous transmission of signals is compatible both with causal connection *and* separation of physical systems). Nevertheless, causal reasoning need not be deterministic in the classical way of defining it. As we will see, there are good reasons to believe that, if we reach a deeper understanding of phenomena, laws of nature will incorporate processes of spontaneous generation of order and self-organization that are incompatible with a Laplacian, deterministic, linear approach. So we will retain causal thinking and locality in ORR, though we shall be ready to give-up determinism.

We will call OR and ORR jointly the thesis of *onto-gnosiological realism.*

Now, *secondly,* let us go straight to the burning question. As Heisenberg expressly recognized in *Physik und Philosophie*, the assertions of quantum mechanics do not respect what we have called "OR", i.e., they cannot be fully objectified and are, thus, incompatible with what he calls “dogmatic realism”. Heisenberg certainly recognizes that every researcher aims at what is “objectively true”. But quantum mechanics goes so deep and so sharply into the minute structure of nature that the searching apparatus provokes uncontrolled changes in the very system it is intended to scrutinize. So we can make assertions not truly about what objectively is, but only about the results of the interactions between measuring devices and physical system. In other words, it is as if all assertions of quantum mechanics were about an entirely new domain: not the quantum phenomena themselves, but the new global systems formed through the fusion between quantum entities and measuring devices (which have a quantum reality of their own). And these quantum mechanical assertions, now referring to this “in-between realm”, would not respect OR either, because the application of any other verification method should engage another measuring device creating another physical system in which, possibly, the former phenomena could no longer be detectable.

For Heisenberg, this circumstance proves nothing against quantum theory as such (or, better, against the Copenhagen interpretation of quantum formalism). It proves only that natural science is possible without strong realist claims. Rejecting dogmatic realism (*viz.,* All scientific assertions respect OR) and metaphysical realism (*viz.,* Things studied by science exist absolutely), Heisenberg proposes a kind of “practical” realism (*viz.* Some scientific assertions respect OR) which amounts to a denial that natural science requires OR and to a confession that idealism or some kind of instrumentalism is an even better foundation. In fact, in light of Heisenberg’s considerations, we could say that these latter epistemic doctrines are preferable because they are, at least, more general, given that only macroscopic phenomena can supposedly give rise to assertions respecting OR, and that idealism or instrumentalist versions of science could encompass assertions respecting OR as well as assertions not respecting it.

Nevertheless, we must make a distinction. We can say that sometimes measuring devices disturb the physical systems in an essential way and that, some other times, the impact of measuring devices on the observed systems can be disregarded. The talk about “disturbance”, and about disturbances that can or cannot be ignored in experimental situations, is plainly consistent with OR. Inconsistency with OR arises when quantum mechanics insists that the measuring device “creates” or “realizes” the properties of a system that was not in a determinate physical state before the measuring operations were done. Heisenberg's argument against OR requires talking about "creation" and not talking about simple "disturbance". In fact, the realism implicated in OR is not put in question in case our measuring devices disturb or do not disturb the system to an appreciable extent, but only in case the measuring devices bring about a kind of "passage" from potentiality to actuality. Indeed, we can always say that, if *p* is know, then *p* is the case *simpliciter,* with a slightly (or even a considerable) deviation due to disturbances originating in the very act of knowing (in its physical basis). It would be something different altogether to assert that there is no *p* before the very act of knowing pushes the physical system to a certain outcome, so that we could not talk about a state independent of the verification method associated with it. So, the fact that measuring is itself a physical procedure that always disturbs the physical system measured (in a degree that can or cannot be ignored) says absolutely nothing against OR.

On the other hand, it is common knowledge since Bohr's essay of 1927 "The Quantum Postulate and the Recent Development of Atomic Theory" that quantum mechanics puts severe limitations on ORR, disallowing causal *and* space-time descriptions that could be simultaneously pursued with an arbitrary degree of precision (technically: they refer to observables of non-commuting operators). According to Bohr, the validity of the superposition principle and of the conservation laws entails the impossibility of a full causal and space-time description. This is so because, as Bohr himself puts it, in attempting to trace the laws of the time-spatial propagation according to the quantum postulate, we are confined to statistical conclusions in light of Schrödinger's wave-equation, and, on the other hand, the claim of causality for the individual processes, characterized by the quantum of action, forces us to renounce to this space-time description.

In fact, for values under the lower limit of $h/4\pi$ for the product of the two measuring uncertainties –the so called Heisenberg's indeterminacy-relations– we can have one or the other, but not both descriptions at the same time. Heisenberg presented for the first time these indeterminacy-relations in 1927. In a *Gedankenexperiment* with a gamma-ray microscope, he reasoned first about the possibility of measuring simultaneously the position and momentum of an electron. Fixing the position of the electron with a total precision would imply an infinite indeterminacy in the electron's momentum, and vice-versa. After that, he extended these indeterminacy-relations to the pair time-energy and found the same lower limit for the product of the two uncertainties.

For a Heisenberg caught in the middle of a struggle with Schrödinger's wave-mechanics, all that these indeterminacy-relations were showing us was no more than the essential discontinuity and unpredictability of the quantum world. He avoided any talk about real particles and (*hélas!*) real waves. However, Bohr had other views on the issue, and a definite non-realistic, non-Schrödingean interpretation regarding the physical meaning of the wave-function. In harsh and relentless discussions with Heisenberg, he stressed that the very kernel of the indeterminacy-relations was the unavoidable wave-particle duality of quantum phenomena and the complementarity-principle he was proposing at the same time. Indeed, as it is generally recognized, with Bohr's ingenious concept of complementarity we have reached the very heart not only of indeterminacy-relations, but also of the Copenhagen interpretation of quantum mechanics as a whole.

Assessing the overall philosophical consequences of this principle, we could say that it tells us the following somewhat disappointing story:

1. Quantum entities *show* us nothing by themselves.
2. If proved by an apparatus, quantum entities can *manifest* wave-like behavior or particle-like behavior.
3. The behaviors of quantum entities are always behaviors *relative to* and *in the context* of a definite apparatus.
4. These particle-like and wave-like behaviors are not manifested simultaneously and by the interaction with the same apparatus.
5. For that reason, the concepts of particle and wave do not contradict each other, given that they are not applied at the same time and in the same experimental context to the same quantum entity.
6. Instead, they exclude each other, but are both jointly necessary to the description of the diversity of quantum manifestations.
7. So, firstly, we have no grips on the quantum entities, but only the possibility of applying to them concepts we have borrowed previously from the macroscopic world of classical physics.
8. Secondly –as it seems Bohr himself has put it– for us there is no such thing as a quantum world, but only a quantum physical description.
9. And, thirdly, quantum entities are a well founded, although limited, conjecture from the macroscopic (classical) world into the microscopic (non-classical) world which returns

back to some processes and phenomena in the macroscopic (classical) world (e.g., the classical concept of a particle gives rise to the quantum concept of an electron movement, which serves to interpret a trace of condensed water vapor in the ionization chamber).

We see that complementarity puts severe limitations to ORR (and OR), concerning not only the possibility of conjoining causal description and space-time coordination, but also regarding the very possibility of taking quantum phenomena as a realm of real entities, i.e., of taking them as appearances of an *actual world* of things and events. As a matter of fact, the quantum phenomenon, as described in Bohr's and Heisenberg's interpretations, lacks the conditions to be considered an *entity* in the full sense of the word: it has no independence from the measuring device, no integrated description of its own multiple manifestations, no concepts borrowed in its very nature, and no such fundamental things as continuity across space-time, determined actual states and separation. And so we face, with the Copenhagen interpretation, the following devastating situation for our hopes to understand nature: fundamental concepts are not realistically interpretable – we must only say that we are constructing a science as if there were a quantum world consisting of waves, on the one hand, and particles, on the other hand, but knowing at the same time that we have no appropriate concepts to understand the way what we are describing as particles combines with what we are describing as waves in the same quantum entity. That is to say: the very concepts of physics we are using do not allow us to construct a sound and coherent representation of *physis*.

All this pertains to the story and the problem of quantum mechanics and is well known to all. Let us only stress that the ensuing development in the Copenhagen paths since 1926-7 only accrues the perplexities. We have, as Jim Baggott points out in his book *Beyond Measure*:

1. *A non-classic interpretation of probability*. Unlike Boltzmann's probabilities, quantum probabilities do not reflect our ignorance about the individual real processes of a complex system, but rather express the likelihood the interaction with a measuring device would then create a determined outcome as the actual state of a physical system. Max Born proposed in a paper published in 1926 the probabilistic interpretation of Schrödinger's wave-function. According to him, the square of the amplitude of the wave-function in same region of configuration space is related to the probability of finding the quantum particle in that region. So the wave-function does not depict a quantum entity, but only our knowledge about the probability of certain outcomes.

The descriptions made by quantum probabilities relate to many experiences. Projecting them onto an individual system entails that the individual system will be a superposition of all its possible actual states. In fact, quantum mechanics stresses that whenever a quantum system can be in a plurality of states, the superposition of states is itself a state in which the system is until some measures are made on it.

2. *An appeal to consciousness in the passage from potentiality to actuality.* The mathematical framework of quantum mechanics does not describe the passage from potentiality to actuality. The collapse of the wave-function is simply supposed to occur, so that the system can pass from the superposition of all its possible states to an actual definite state. Facing the infinite regress implied in the fact that the measuring apparatus is itself a quantum entity, entering in a superposition with the physical system under observation, von Neumann introduced his famous thesis that the wave-function collapses when and if the system interacts with consciousness. In fact, even the sense organs and the brain are quantum systems entering in a new composite wave-function. Only consciousness is supposed to be a reality beyond the physical realm that puts an end to the infinite regress.
3. *Entangled states and non-locality.* Two particles that have interacted are described by a single two-particle state vector. When a measure is made on one of them, the state vector collapses into a definite state, forcing the other particle to realize instantaneously a specific correlated state, no matter how far it will be from the former (it can be on "the other side" of the Universe). Bohr began to give up the talk about "disturbance" introduced by measuring operations in his rejoinder to the EPR argument in October 1935. Since then, he defended an indeterminacy of the system before its relationship to an apparatus that is tantamount to a real action at a distance in the case of entangled particles. This was a direct vindication of non-locality. The particles lost their individuality in space-time. After him, Bell's inequality theorem and experiments promoted by Aspect and Wheeler gave experimental, but very controversial support to the reality of entanglement.

Must we give up OR and ORR together, that is, must we give up onto-gnosiological realism and the general way we used to do science? Must we *alter* the very concept of scientific knowledge? Is this a reasonable price to pay: entanglement, that is: non-locality; *ad hoc* consciousness, that is: the determination of the physical world relying on a non-physical entity; superposition, that is: the bare actuality of potentiality; and complementarity, that is: renunciation even to a not full-fledged realistic description of a quantum world?

To finish with this point, let us only say, *thirdly,* that this is not such a desperate situation. There have been winds of change blowing since 1926-7. Facing the puzzling aspects of quantum wave-like and particle-like manifestations, the French physicist Louis de Broglie proposed a description of the inner structure of quantum entities that turned these disparate manifestations into phenomena of a well defined underlying quantum reality. Against Born's interpretation, de Broglie proposed in 1926 to view quantum entities as singularities (point-like particles) moving in a real field, while, at the same time, there was a second field which had the statistical and probabilistic significance of Schrödinger's wave-function, as interpreted by Born and Bohr. After this first proposal, de Broglie simplified his theory about the inner structure of a quantum entity. It was, now, a point-particle moving in a continuous, real wave-field. The particle follows the wave-field, and its position is more likely to be in those regions where the amplitude of the wave-field is larger. This is precisely "la loi du guidage", as de Broglie himself put it: the particle in not only directed by the wave-field, the particle is nothing more than a singularity of the wave itself. Thus, contrasting with Bohr's rather mysterious talk about complementarity, we have no duality between waves and particles and no permanent necessity of speaking the language of waves or the language of particles, never knowing how something can reveal both particle-like behavior and wave-like behavior. On the contrary, we have now an insight into the deep structure of a quantum entity that is able to turn such disparate manifestations into well defined and predictable phenomena of one and the same entity. The interpretation of the double-slit experiment is now trivial: the singularity passes through one and only one slit, while the real wave passes through both slits and produces constructive and destructive interferences determining the path of the singularity. No need to say that, contrary to Copenhagen interpretation, every particle has in its field a definite position and a definite momentum. Probabilities revert now to their classical significance: they express only our ignorance about the intricacies of the quantum world. This theory by de Broglie was developed by Bohm a few decades later. He introduced a non-classical quantum potential, *U,* to explain the motion of particles. When this quantum potential decreases to zero, the equations of motion of the de Broglie-Bohm interpretation revert to the classical equations of Newtonian mechanics in the so-called Hamilton-Jacobi formalism. Recently, Croca and his associates proposed a reappraisal of the de Broglie's theory, as it will be profusely explained in this book. Taking de Broglie's realistic approach, Croca distinguished between the real-wave, now called theta-wave, and the point-like singularity within the wave, called acron, that is, the higher energetic region of the whole structure.

As we can see, the clash between Born's and Bohr's interpretation, on the one hand, and de Broglie-Bohm-Croca's interpretation, on the other hand, is not a simple disagreement at the level of explicative concepts. On the contrary, referring to our HR above, we must say that there is a real conflict at the level of constitutive concepts. We must, then, expect that a new realm of phenomena and new facts will be uncovered by the challenging theory. As a matter of fact, the initial approach by de Broglie predicts superluminal velocities for the singularity; recently, in 1993, Peter Holland emphasized in his book *The Quantum Theory of Motion* that de Broglie-Bohm theory had something different to say about the time taken by particles to tunnel through a potential barrier. Recent work by Croca about tunneling shows some different results too, and, more importantly, some new phenomena at the sub-quantum level (concerning theta-waves) are coming near to being discovered and converted into new facts of the quantum world.

In a word, de Broglie-Bohm-Croca's realistic interpretation of the wave and of the singularity (Crocas's acron) as a point-like region *in* the real wave bypasses the conundrums and conceptual perplexities of the Copenhagen interpretation: there is no quantum jumps, no collapse of the wave-function, no mysterious contribution of consciousness to measuring operations, and probabilities return to their classical meaning. In addition, it seems that the realistic interpretation is also able to point in the direction of new realms of phenomena (at the sub-quantum level) and to constitute entirely new facts. Only the subsequent experimental and conceptual work can show what the final decision will be.

3. Underpinning onto-gnosiological realism: knowledge and its entities

Meanwhile, we need to come to a decision about the following double way of considering the general issue of quantum mechanics: is quantum mechanics really presenting us new and utterly insoluble paradoxes about knowledge and about nature (as the

Copenhagen interpretation suggests), or is quantum mechanics just destroying some naïve conceptions we had, as to give rise to a new coherent conception about knowledge and its object (as a debroglian realistic interpretation would maintain)? The answer is somewhere in between these two extremes. Quantum mechanics showed that classical ideas about nature and knowledge were inapplicable to it – this is undeniable. However, we have reasons to question whether the paradoxical look of quantum mechanics is an ultimate and insuperable situation (and if so, in what regards), or whether these paradoxes can be overturned in a new post-classical conception that is still to come. In addition, we must remark that, on the one hand, quantum mechanics corrected some oversimplifications about knowledge and its object, and these very corrections have diminished, in turn, the weight of quantum paradoxes; on the other hand, some paradoxes of quantum mechanics are still based on the entrenched naïve ideas, and it is foreseeable that the criticism of those ingenuities will contribute to dissolve them.

Up until now, a huge literature emphasized the paradoxes: entanglement, measuring acts collapsing the wave-functions, wave-particle duality, a general lack of strong objectivity and the rise of a nondeterministic, somewhat irrational description of nature. Let us now stress, the other way around, both the naïve conceptions we used to be acquainted with and which quantum mechanics have begun to beat down, and those naïve conceptions quantum mechanics still accepts without a doubt.

Given their special character, we will call them "fictions". The word is used here not as meaning something non-real or patently false, but in the following precise sense: a fiction is some assumption not justified in itself that allows us to think *as if* some things really were true, so that we embed phenomena in a particular conceptual framework and give them a correlated meaning. Fictions are in most cases simplifications and highly abstract hypothesis that dispense us to inquire into the true nature of reality. They are not a theory and they are not constitutive concepts either, they are, rather, a useful device to deal with complex realities in the absence of a true knowledge or a sound theory about its nature. For instance, the liberty and responsibility of people brought to justice is an overall fiction that allows the adjudication of guilt or innocence in a trial: the jury decides as if the defendant were really free and really responsible of all the criminal acts he is accused of. However, the full liberty and responsibility of individuals in society are assumptions never proved by anybody. Political theory also furnishes us with a lot of fictions. The idea that the commonwealth began by means of a mutual pact between individuals, so that this social contract and not brute force counts as the very beginning of the state, is an evident fiction developed by some political thinkers like Thomas Hobbes or John Locke. This fiction allowed them to consider political society as if all individuals were free and equal from the start, and to justify political obligation before the sovereign as if it had sprung from an original act of consent (the original pact).

We cannot take a simple pragmatic approach to fictions. The question is not simply whether they are useful, but also whether they are true or, at least, plausible assumptions. We cannot have an understanding of reality fully based on fictions. They must retreat in face of an effective knowledge of what there is. The fiction about the liberty of individuals is a good approximation to truth, if we disregard the metaphysical question of free-will and define liberty in terms of voluntary acts. Besides, in order to prevent social disorder it is useful to have a penal system, and penal systems are based on criminal law, which depends on the idea of imputability, that is, of the liberty and responsibility of individuals. The fiction of the original contract is, however, entirely implausible nowadays, and this implausibility hinders all utility it may have had in the past: nobody believes it now and nobody acts in accordance with it, that is to say, as if it were true.

Classical gnosiological thinking was also prolific in fictions. Let us examine those that are most important for our issue.

1. *The immaterial eye fiction,* that is, knowledge mostly conceived as a simple action of taking notice of what is, i. e., as a (theoretical) regard that does not affect or alter the things looked upon. Vision was paradigmatic for this fiction about knowledge. And theory, conceptual thinking in general, was often conceived as an intellectual vision too – as an "intuitus mentis", as Descartes named it. The ancient idioms *theorein* and *contemplare* had the same idea behind them in the ancient noetic parlance. According to this fiction, all happens as if things were what they are and, then, a supervening regard only came to register their existence and properties. Naïve realism uses this fiction surreptitiously in order to talk about a reality that is what it is independently of being known or not. For neutralizing the impact of knowledge on reality, this fiction suggests that knowledge is an event belonging to a mind that forms no part of the physical-material universe and does not produce any effects on it. Linked with this

fiction there is, thus, a sketchy dualism between matter and mind. Not so surprisingly, von Neumann's conception about the role of consciousness in measurement only radicalizes this fiction of the immaterial eye: instead of merely taking notice of what things already are we now have the idea of a non-material, non-physical regard that makes things happen and be what they are. However, this fiction about an action of taking notice that has no roots and no effects in the reality concerned is completely untenable. Quantum mechanics, without Copenhagen thesis about the creative power of measuring acts, suggested the idea of an inevitable (even if depreciable) disturbance of physical systems by the very act of knowing, which is an obvious state of affairs when the act of knowing is not a pure theoretical inspection, but an experimental operation involving technical apparatus (but even macroscopic vision is, after all, a physical event that disturbs infinitesimally the surrounding world). Thus, contrary to this fiction, we must considerer, from the very start, the act of knowing as a physical action which produces modifications in the things that are its objects, so that knowledge never reaches a nude reality, undisturbed by the very act of knowing. We can say as a motto: every act of knowing a physical universe is itself a physical event in the universe.

2. *The certain-inside versus the uncertain-outside fiction,* that is, the idea that knowledge is an event taking place in the internal arena of consciousness, in a "theatrum mentis" (inner stage), so to speak, so that reality is conceived as a realm of "exteriority" unattainable by a direct grasping. This is one of the most widespread fictions in gnosiological thinking. Descartes inaugurated a doubt about the existence of an external world based on the assumption that the mind has direct access only to its own ideas. If the mind is closed in upon itself, reality becomes a matter of "exteriority", while the mind moves back to an extra-worldly "internal" space. This gives a semblance of plausibility to the extremely odd idea that there is a split between a material, external universe, and an immaterial, internal mind. From now on, under the impressive suggestion of this fiction, the events in the internal stage of the mind are considered as certain and beyond all conceivable doubt, while things in the external universe –to which the internal events allegedly refer– are uncertain and doubtful. Malebranche, Berkeley, David Hume – all of them were cases of this inner-outer, certain-uncertain fiction. Kant tried to amend this in his famous "Refutation of Idealism" in the *Kritik der reinen Vernunft.* His point was that the inner sense is possible only through the mediation of the outer sense (the intuition of time depending on the intuition of something permanent in space), so that the certainty of the outer sense is equal

to the certainty of the inner sense. Nevertheless, Kant's argument is pointing only halfway beyond this fiction, because he continues to accept the very distinction and a definition of physical reality in terms of exteriority relative to the mind. One of the most conspicuous consequences of this fiction was the Humean thesis that, when the mind is affected by some external objects, the only things that are given to it are its own internal modifications, called "impressions", so that the mind does not have a solid ground to state, for instance, "The thing perceived is hot", but only to say "There is now a sensation of hotness in me". This is tantamount to saying that any measuring apparatus, a thermometer, say, can only report its own internal states and not causally refer these states to an objective reality. As a matter of fact, if, according to this fiction, this reference takes the form of a mapping of the internal states onto an external universe, the skeptic will always raise doubts as to whether there is truly an external reality outside" the mind to which these internal states refer. When quantum mechanics considers the measuring apparatus as the only thing whose states physics can describe, it suffers somewhat from the same Humean delusion. Against it, we must state that any sensible organism interprets its states as a result of the interconnection between itself and the surrounding world. These states do not represent something external – they do not "depict" an external reality. We must drop this way of considering things. Those states are *states of reality,* not of an "inside" (the mind) referred to an "outside" (the "external" world). This reality is not bare reality (a deeper consideration shows that this concept of "bare reality" is meaningless), but reality submitted to the set of operations that we call "interaction with the measuring apparatus" or "interaction with a living organism." So we must say: an apparatus (or a sense organ – vision, say) is not a device to scan a reality external to it, but a procedure to induce a certain kind of events in reality. For instance, the complex system eye-brain-consciousness is a device to bring about a chromatic world. "Outside" this system there is no chromatic world at all, i.e., in order to have a chromatic world we must insert in reality the set of operations produced by the system eye-optical nerves-brain-consciousness (by itself, the reality from which we are starting is not "nude reality", but already the result of other sets of interconnected and stratified operations). Thus Bohr's hunch was half-right after all. In a way, the measuring apparatus pushes the physical system to a certain outcome that was not there before. The apparatus (or our sensibility) is not a way to figure out an outside, "external" reality – it is part of the same reality, and a more complex level of reality, bringing about phenomena that constitute new realms in their own right. Bohr's general conception about the nature of an apparatus (or the sense organ of a living organism) is then quite right when stating, as in the essay of 1935 “Quantum Mechanics and Physical Reality,” that the procedure of measurement has an essential influence on the conditions on which the definition of the physical quantities rests. The fault of Bohr’s conception lies in his refusal to account for the dependence of physical properties upon the experimental apparatus in terms of causal processes producing growing levels of complexity.

3. *The fiction of the label-like properties of objects,* that is, the idea that objects by themselves have individualizing, well-defined properties before any interaction takes place between them. Notwithstanding the seemingly strong evidence supporting this idea, it is a naïve way of thinking about reality. A property is not like a label that a thing has in order to be distinguished from any other thing. Things do not have properties – things acquire properties as long as they interact with each other. Every property expresses an interaction. For instance, speaking about the polarization of light or the spin of an electron, which are intrinsic properties, is a way of expressing some patterns of interactions of light or electrons with some other physical entities (like a filter or a magnetic field). Quantum mechanics contributed powerfully to a break down of this old naiveté of ontological and gnosiological thinking. As a matter of fact, the best examples to illustrate this are given by quantum entities, because they cannot be described as macroscopic objects that are the apparently enduring bearers of permanent properties. Nevertheless, in other realms, the same general conception applies. Talking about the sincerity or the generosity of a person means that some behavior usually took place when this person was submitted to a specific social situation (say, being always veracious in the expression of his own feelings, giving assistance to others, and so on). It makes no sense to talk about the properties of being sincere or generous of a person that does not have social interactions with other people. The fiction of a label-like property of objects gave rise to an ontology that conceded a primary rank to the concept of “thing”. In accordance with this fiction, ultimately we could even speak of a universe composed of just one thing which had, say, properties *a, b* and *c* instead of properties *d, f* or *g,* even if this way of putting things amounts to an obvious non-sense. In this respect, metaphysics has for a longtime discussed the “principium individuationis,” i.e., the conditions that allow a thing to be one and, at the same time, distinct from any other. A multitude of answers was given to this secular problem, from Aristotle and Aquinas to Leibniz and Kant. The Leibnizian way of dealing with the problem was a very interesting one. It consisted in putting the principle of individuation not in a space-time location but instead into form, that is, by way of determi-

> nation, and in considering that the individuality of a thing is given by an infinite series of predicates, describing all its real properties (the word "real" meaning, in the scholastic jargon Leibniz was using here, a property that is inherent to the thing itself and that is not a relation to another thing, i.e., something expressed by a monadic and not by an n-adic predicate). However, so far, so… bad, we could say, because this is the same as thinking candidly that we can answer the ontological question about what there is by simply stating that there are a plurality of substances (i.e., bearers or subjects of a collection of real predicates), and that substances differ from others in having some label-like properties peculiar to them or a set of properties that is not replicated by any other thing. Notwithstanding this naiveté, when we wonder why the infinite set of properties of one substance cannot be replicated by another thing, we come to an interesting answer: Leibniz suggests that every property of one thing is necessarily correlated with a correspondent property of any other thing, so that, if two sets of properties were not correlated but wholly identical, they will constitute the very same substance, expressing the universe from the same point of view. That is to say: it is true that, for Leibniz, substances are series of real predicates and are closed in upon themselves, according to the label-like fiction; nevertheless, each real predicate of one substance is necessarily in correlation with at least one property of any other existing substance. This is tantamount to saying that properties express universal interconnections of one substance with all substances in the universe. Going beyond Leibniz's metaphysics, we could say that properties are just the expression of causal interconnections, something like the result of an interaction between all physical realities. In a word: a property is not a state a thing simply has from the start, but a state a being acquires as a result of an interaction. And if we can say with Leibniz that a substance is an infinite set of properties, this will mean now that a substance is an infinite process of interaction with other things. Thus we must take determination or property not as a label, but always as an interaction result. The fiction of things as bearers of properties is overturned: a "thing" is now just a never-ending process of causal interactions in which it gets determination. Spinoza said once *omnis determinatio est negatio*. Adjusting a bit Spinoza's dictum, we could put it as motto: *omnis determinatio est interactio.*

In putting these things together, we must say: (i) physical knowledge is itself a physical disturbing process involving measuring apparatus (the same applies to the sense organs of our perceptual acquaintance with the surrounding world); (ii) a measuring apparatus is a physical way for producing phenomena of a special kind; and (iii) properties of physical systems are the results of interaction between these very systems and other physical systems (namely, but not forcibly, an apparatus). This is our non-classical version of onto-gnosiological realism: not a word about a reality that is what it is regardless of being known or not; also not a word about a conception of knowledge as a non-disturbing process; and, finally, a place for the observer, and for a physics closely related to the observer's point of view in a universe that goes beyond the observational content (linked to the measuring apparatuses or just to the sense organs) by means of a causal connection between this content and the underlying reality. Keeping this in mind, we will not only see the limits of classical gnosiological theories, but we will also have some glimpses into what is solid and what is doubtful in the paradoxes quantum mechanics presents to us.

As a matter of fact, if we examine the major attempt to give an epistemological foundation to classical Newtonian mechanics, that is, if we turn our eyes to the *Kritik der reinen Vernunft,* by Immanuel Kant, we will see that the operations involved in knowledge are described as follows:

I. Univocal location of any event in space and time. i.e., space-time coordination;

II. Causal connection of any event with any other event simultaneous to it (reciprocal action) or situated in the future (causality in a narrow sense), i.e., settlement of an universal causal net;

To those operations of coordination and causation the following conditions apply:

A. Definition of an object in terms of continuity of events across space-time;

B. The principle of conservation (of "matter", or better yet, of "energy") as a necessary condition for the passage of an object from one position to other (contiguous) position in space-time and from one state to another;

C. The principle of determination of any state of an object by (i) its previous states (if it is a closed system), plus (ii) the causal interaction with all other objects (if not a closed system);

D. The principle of complete determination of an object regarding all its possible properties.

Kant (and Newton too) thought that I. was a simple matter of Euclidian geometry, plus the reference to a universal time order. It is well known that the special theory of relativity brought major complications to this very simple idea. An univocal location of events and determination of distance between pairs of events turned out not to be measuring the distances in space and time relative to a given frame of reference, but determining a new magnitude, invariant to all possible observers, named "space-time interval." However, the great correction relativity introduced relates to II. – the quest for a maximal velocity of signal transmission destroyed the (supposedly) Newtonian idea of an instantaneous action at a distance –as far as gravity is concerned– and the Kantian assumption that there is a causal web connecting simultaneously all objects in empirical space.

Nevertheless, it was quantum mechanics that introduced a real rupture into this classical scheme. And so, we come, at last, to the paradoxes. To begin with, the possibility of performing conjointly coordination operations and causal connections to an arbitrary degree of precision was severely restricted by the complementarity principle; as we saw above, either we have position (doing coordination operations) or we have momentum (developing causal reasoning). Moreover, the quantum entity – as the Copenhagen interpretation stresses– is by itself *not* determined in its position and momentum under a certain lower limit, which turns out to be the Heisenberg's indeterminacy relations. Epistemological uncertainty (Heisenberg's *Ungewissheit*) is based on ontological (physical) indeterminacy (Heisenberg's word was precisely *Unbestimmtheit*). This directly rebuffs D. In addition, quantum mechanics also shakes A, C, and D anew with its quantum jumps, the restriction to probabilities, and the superposition of linear states before the interaction with an apparatus produces a determinate state through the collapse of the wave-function. The only principle still unshaken is B, if we interpret it as an energy conservation law (Bohr himself pondered several times if he had to drop it). In turn, the non-locality of entangled states is a fresh departure from the constraints raised by relativity and a return to a Newtonian conception of something like an action at a distance connecting all things in the universe.

What does a neo-debroglian approach mixed with our onto-gnosiological realism have to say about all this? That was the question. To begin with, let us say that quantum entities are certainly not like classical, macroscopic objects. This circumstance imposes some qualifications onto A and C: first, it is a matter of discussion if we do not have something like acron jumps *inside* the finite theta-wave (if we consider that the real theta-wave, despite its extension, is all contained in each time-point, say t_n, the subsequent position of the acron in t_{n+1} can be any point on the theta-wave in t_{n+1} even if not contiguous to the point it had in t_n – tunneling could be an effect directly related to this, with the acron "jumping" to the region of the theta-wave that stands behind the barrier); second, the displacement of the acron along the theta-wave is nondeterministic – it integrates stochastic process and gives rise only to a probabilistic description. However, despite this non-classical view, we can reach a rather different general explanation for the reason why we cannot simultaneously hold coordination and causal determinations to an arbitrary level of precision. In fact, considering what we said above, we must ponder freezing all talk about complementarity and try to substitute for it the concept of pairs of mutually-dependent properties. We can define this concept as follows: properties A and B are a pair of mutually-dependent properties if any alteration in one of them disturbs the other, so that we cannot go from the determination of a precise value of A to a precise value of B and return from B to the same value of A, and vice-versa, because the alteration of one quantity produces an alteration in the other quantity in a probabilistic, nondeterministic way. Now we could say: given that a quantum entity has at each moment a set of interactions with other quantum entities from which it gets some precise properties defining its state, and given that some interactions interfere with other mutually-dependent properties, disturbing the values they have (position and momentum, for instance), a quantum entity must be considered as a *balance* always in adjustment between the properties it has (from previous interactions), the new properties it gets (from actual interactions), and the disturbing processes that impinge chains of alteration-loops in the mutually-dependent properties. That is: a quantum entity is actually determined in all properties it has, it has definite position and definite velocity, even if it is in a never-ending process of alteration-loops between its mutually-dependent properties (this is the same as stating that we cannot have simultaneously a precise measuring-value for them all). Thus a quantum entity, if not closed upon itself but submitted to some measuring process, is never stabilized in a well-defined global state.

To conclude, we must state that our approach must reject the classical principle of complete determination. Kant said that it is not a condition for the possibility of experience, but only a rational rule for conceiving what a thing is, tracing for it a place in the sum of all possibilities. As he puts it in his *Kritik* (B599-600), "Every *thing*, as regards its possibility, is … subject to the principle of *complete* determination, according to which if *all the possible* predicates of *things* be taken together with their contradictory opposites, then one of each pair of contradictory opposites must belong to it." That is to say: to conceive the possibility of a thing is to put it (better: to conceive the possibility of such a procedure) before all pairs of possible predicates and to decide for each one of the pair, so that a thing is conceived as *real* when it is (or is taken as) completely determined by all conceivable predicates. Two things are different if and only if they have different global series of predicates. We approach Leibniz. And, if we enter the realm of physical knowledge with this principle in hand, we come to the idea that any physical object must be in causal interconnection with all objects in the universe. As a matter of fact, comparing one thing to all possible predicates turns now into a process of putting a thing in connection with all other existing things. So we must embrace the idea that there is a universal causal web linking each thing with all other things, so that the full knowledge of one simple physical being would imply the knowledge of the physical universe as a whole. We would come near Laplace's demon, which dwells in a full deterministic universe, where everything is connected to everything. However, if we do not drop the relativistic idea of a maximal finite velocity for signal transmission and causal connection (no matter if it is *c* or otherwise), given that a property is an interaction, as we said, and that an object has no interaction with all other objects (relativity's *must*), we cannot define a real object as something which is completely determined regarding all is possible predicates, because a physical object *never is* in causal connection with all physical objects and so necessarily lacks the (possible) properties related to those interactions: in this regard, it is patently undetermined, and it is just *as partially undetermined* or as *incompletely determined* that we must affirm its very existence.

4. *Physis* – what is it?

Here is the question that turns all of us into no more than apprentices. We will try to get some glimpses beyond the customary paths, even if by taking the risk of being a bit speculative.

For a long time, natural philosophy fit comfortably within the Cartesian split between matter and mind. Descartes thought that the former, pre-Galilean way of conceiving the physical realm suffered from a huge misconception, namely, the blend of properties pertaining to mind and to matter, as if they formed a whole. In his criticism of scholastic and Aristotelian physics and biology, concepts like “sensitive soul”, “vegetative soul” or “substantial form” were denounced as a kind of anthropomorphic projection into the material realm of concepts belonging only to mind. Specifically, the scholastic physics, following Aristotelian principles, made a massive use of the concept of form, which, from Descartes’ point of view, could only be understandable through the erroneous import of properties that pertain exclusively to mind and, for that very reason, eventually veiled the properties that truly belong to matter.

For the sake of a critical assessment, it would be important to distinguish Descartes’ explicit argument from what is Descartes’ ultimate point. The argument starts in metaphysics. It begins with Descartes’ double thesis that his mind is better known (to him) than his body (or any other “outer” body) and –this is crucial– that he himself knows undoubtedly that he has a mind while it is doubtful whether he has a body linked to his own mind. Long after this initial split between certain self-knowledge as “mens” and doubtful self-knowledge as “corpus”, Descartes makes an additional appeal in his *Meditations* to the “veracitas dei” in order to settle that what is clearly and distinctly conceived of one thing belongs certainly to it, and that – following from the former thesis– if one thing can be conceived without the other (i.e., without the properties that are clearly and distinctly conceived in the other), then this very thing is separated from the other, or exists apart from it. The conclusion was, at this point, looming very near: considering that mind and body could be conceived apart, mind and body also could exist apart, so that the science of bodies and the science of minds do not conflate.

The argument is flawed in several regards. The appeal to the *veracitas dei* proves nothing, because the certainty about the existence of God depends circularly on the clear and distinct rule; in addition, it is by no means sure that we can even conceive a mind without the understructure of a body and, conversely, a body without the organization superimposed by a “mind”, as the argument settles as premises (nothing that belongs to mind belongs to body, and nothing that belongs to body belongs to mind, states Descartes). This double assumption that we can *understand* what a body is without some properties supposedly belonging to mind (more about this later), and, the other way around, that we can have a *full concept* of the mind (as a “substance”) without the properties belonging to body, this pair of assumptions are precisely Descartes’ point. He never really demonstrated them; he simply took them as true premises for his overall argument (and as the faith underlying his entire work as physicist, embryologist, biologist, and so on).

But what is mind? And body? What consequences follow concerning physics? Let us see more closely what Descartes' point really was. It was a very bold bet: nothing less than suppressing systematically in the description of nature the reference to patterns of organization –which were entrenched in the concept of "form"– in order to come to them as results of the mechanistic, blind and not finalistic local motion of matter alone. That is to say: while Aristotelian-scholastic physics was going top-down, from the organization-pattern, called "form", to the material base in which it was stamped, going down successively until the ultimate "undetermined matter", the so-called *substratum*, was reached, Descartes' bet was to go bottom-up, starting with autonomous laws of matter in order to arrive at the organized structures not as principles, but as results of these core-laws. Given that the reference to "form" (i.e., to organization patterns) was removed from the front door in the study of nature, physical substances were reduced to matter, and matter to motion. The laws of matter were, now, simple laws of impact and communication of movement. Physicist had to discuss the relation between such scalar and vectorial quantities as force, movement, velocity, acceleration, mass, and so on. Regarding the organized top-structures, like living beings (or even crystals), the old names "substantial form" and "soul" were, thus, no longer applicable; considering that they were explainable in terms of the local motions and arrangements of their own constitutive parts, their new and true name was instead (natural) "machines".

Surely, the old concept of "form" was poorly illuminating. It explained really nothing. Notwithstanding, it had several advantages in the understanding of nature. Namely, it directed the attention from the very start to patterns of organization, and not simply to bits of bare mass (the "quantitas materiae"), and, in addition to this richer point of view, it endorsed a broader concept of movement, which encompassed not only local displacement, but also the phenomena of growing and alteration, which were characteristics of structured and organized beings. The Cartesian "reform" of physics was, then, based on several very hard although controversial assumptions. First, that bare matter could be considered by itself as a realm of local motion and forces acting by impact, that is, that kinematics and dynamics were the very core of physics; second, that organized natural structures could be explained mechanically, without the involvement of teleological principles and final causes; third, that every time we were talking about something like a "plan", an "organizing principle" or an "intention", we would be talking about mind, i.e., about a psychic being, and definitively not about matter.

So it was with Descartes. What we gained by this *tour de force* is well known to all. No need to describe it again. Modern natural philosophy took physics as the fundamental science, and physics was defined as the science of local motion until Faraday and Maxwell's works in the 19th century about electromagnetism introduced a new branch. In line with this leading old idea, in the late 18th century Kant tried to present nothing less than an a priori deduction of the object of physics. In his *First Metaphysical Principles of the Science of Nature,* he presented physics as the science of matter, and the science of matter as the science of motion, to conclude, supposedly still in an a priori fashion, that the several parts of the science of matter in motion were Phoronomy (Kinematics), Dynamics, Mechanics, and Phenomenology (in a very particular sense).

But Kant himself realized at the same time the limits of mechanistic explanatory schemes. Let us return briefly to Descartes' theoretical decisions. They were certainly a tremendous step forward. But they were also a dramatic impoverishment. First of all, there are natural processes that seem to be driven by something like a plan, or a pattern, that determines in advance the disposition and the arrangement of the parts. Living organisms are such a case. But also global arrangements like the ones we can see in crystals or in snow and ice patterns suggest to the natural philosopher that there is something like a "natural technique" or a "natural plan", that is, something like an unconscious natural intention (or propensity) in several physical processes. However, the very center of this insight into the deep structure of matter lies in organization as such, not in finalistic or intentional processes. Final causes or the talk about a "natural technique" or a "natural intention" are a rather bewildering response to the problem of organization, i.e., to organization as a phenomenon of nature in need of a *natural* explanation. We can see now what happened: Descartes' reform suppressed from the science of nature any talk about final causes or intentions acting in natural phenomena, and, in so doing, the fact of organization, to which the concepts of final causes and forms used to apply, vanished from the regard of the natural philosopher. Refusing a bad answer to the problem of natural organization patterns (substantial forms, final causes, and so on), Descartes imposed to drop the very fact of organization or, better, the concepts that constitute organization as a fact. This is precisely the first impoverishment we wanted to emphasize: organization was formerly picked-up in nature through the concepts of forms, inner intentions, ends and plans; all those concepts were now interpreted through the model of the purposive action of a conscious mind and, for that very reason, they were excluded from the science of matter; as a result, organization was regarded only as a secondary upper-level phenomenon of something more fundamental, namely, as a consequence of the pure and simple local motion of matter. Now we can see the second dramatic impoverishment Descartes' reform brought with it. Organization is a high-level phenomenon that is not explainable by a linear reasoning going from the parts to the whole and considering the whole as the simple sum of the parts. Organization is a pattern that emerges on an underlying multiplicity of elements, but in such a way that it *seems* that it was the pattern that directed in advance the disposition and arrangement of these elements. This was the "intentional" or "teleological" delusion to which the concepts of substantial form and final causes gave expression. Even Kant recognizes that organized structures, such as living beings, exhibit a complexity that lead to think *as if* the whole was not the result of the parts, but, contrariwise, as if it was the whole that commanded in advance the disposition of the parts. Kant considers, thus, that organized beings put an unbreakable limit to mechanistic explanation. Nevertheless, his proposal that we must reflect as if there was a "natural wisdom" and a "natural technique" (another fiction: the teleological fiction, here somewhat lessened by Kant's famous distinction between determining and reflective judgments) suffers from the old fault of considering that teleological concepts are the best (or even the sole) answer to the phenomenon of organization. As Kant saw it, organization puts before us an epistemological problem: we do not see how organization can be thinkable as a natural phenomenon (without teleological concepts). In refusing teleology –even if it simply refers to the unconscious patterns enclosed in the concept of a natural form– by assimilating all forms of design to the purposive action of conscious minds and in refusing, obviously, to talk about properties of minds in the science of nature, Descartes' reform closed at the same time all other paths to the organization phenomenon, so that the only intellectual scheme able to explain the top-properties of an organized natural structure was to try to recover them as an effect of the blind arrangement of the parts, as if they happened by pure chance.

Now the question is: how can we constitute the phenomenon of organization as a *natural fact*? We must give-up, obviously, the bold and straightforward teleological concepts. We can no longer think as if the whole preceded and directed in advance the arrangement of the parts. Instead, in order to take organization as a strict natural phenomenon, we must consider organization as a *self*-organization process.

For doing this, the following constitutive concepts are worth being considered:

Knotting – i.e., a tendency to join on the basis of some common or matching feature, like, for instance, frequency, energy level, opposite charge, or pairs of opposite spins, etc.: the entities resulting from knots can be "homeomeric" (the parts add to produce only one entity of the same nature, like the superposition of waves in phase), or "heteromeric" (the parts join to produce a twofold or n-fold entity, like opposite electron spins in an orbital).

Reinforcement – i.e., jointed physical entities strengthen the knots by mutually catalyzing the elements necessary to each other, so that they form whole that conserves them and constitute a new entity that interacts with the surrounding medium in a new global way; the systems formed by reinforcement can be stabilized systems or unstable systems, that need to get in the environment ever new conditions in order to endure.

Economy or least dispense – i.e., the feature that knotting and reinforcement are favoured because they reduce the losses that each entity in isolation would have through the interactions with the surrounding world, as if nature obeyed a principle of least action or as if nature chose according to a principle of the good path; instead, nature simply conserves the elements that get the conditions for preserving themselves by knotting and reinforcing, while the others disappear or enter other wholes in a process of physical natural selection, so to speak. Crocas's principle of eurhythmy goes this way: it speaks about good paths indeed, while avoiding the enchantment of teleological concepts.

An organized system is not a necessary event of nature. It has stochastic processes at its base and, for that very reason, is not predictable in a full deterministic way. A science of self-organization must deal with non-linear processes and, thus, it has to overthrow the old Cartesian linear ways of thinking. Yet, only organized structures can last and remain in nature, so that we can see the springing of *physis* as the coming about of organized systems in never ending growing degrees of complexity. We reach then a pretty different conception about matter. Descartes and modern thinking in general had a conception of matter as something which was lying passively under universal and unbreakable laws. Modern thinking used many times the fiction of God's legislative will in order to understand matter as such a passive substratum. Very suggestively, Descartes said that God gave His laws to nature as a king to his kingdom. Now we have some glimpses at a deeper dimension of matter. They show us matter as a process of self-organization, i.e., not as something that is just under laws, but as something that creates the lawful patterns (or the "forms") of its own existence. We can finally see *physis* or nature as an ever-growing process of organization; that is to say: a never-ending process in which emerging patterns give the basis for the springing of new, more complex patterns, and so on indefinitely (are there laws of breakdown processes beyond a certain upper-limit of complexity?)

How deep does this self-organizing process go? Generally, we perceive it clearly in living organisms. But this is already halfway through the story. In order to characterize life, we must talk about cycles, i.e., loops of internal processes, replication, i.e., production of new similar organisms, agency, i.e., some active imprint in the surroundings, and cognizance, i.e., a kind of discernment or sensitivity to the environment. All this supposes the more basic processes of knotting and reinforcement, which belong to the lower levels of organization processes. Thus, our guess is that organization starts at the deepest level, and that all matter is a continual organization process, so that there is nothing as naked matter or some substance that is passively under laws (of motion or else) which are superimposed unto it. As we see it, when the simpler quantum entity springs in the theta-wave of the sub-quantum medium, the photonic acron, this *is* the emergence of organization at the most fundamental level. The photonic acron, while having zero rest mass and no charge, is indeed an already complex, organized entity: it has a physics that others will describe in this book.

Let us finish by aligning several insights about what the cosmos seems to be from this new point of view.

1. There is no initial singularity, but an everlasting sub-quantum medium.

2. There is no creation of the universe in an initial expansion, but a permanent process of creation of matter as a perturbation of the sub-quantum medium – this perturbation (whose physics is still to come) is the emergence of the acronic, quantum entity.

3. There is nothing before space and time, preceding the putative creation of the universe, but there is a permanent sub-quantum medium to which the concepts of time and space no longer apply.

4. In order to describe the complexity of the universe, we do not need to start with a violent expansion and to adjust *ad hoc* the initial parameters in order to recover the structure of the existing universe (e.g., the formation of galaxies), reasoning as if the development of matter was a blind, mechanistic and all-deterministic process completely defined in advance by the sole initial conditions; instead, we must follow the successive levels of complexity, starting from the fundamental formation of quantum entities in the sub-quantum medium and ascending to the upper levels, understanding the propensity of matter to create ever new patterns of organization. We must give matter a chance, so to speak: if we allow, matter will find its way…

5. Entire universes can spring from the sub-quantum everlasting medium, having their complete story, their emergence and downfall; in this process of genesis and destruction, it is likely that many worlds have come and are still to come, and not only a unique universe, like the Big Bang story parochially suggested us.

For if we have the modesty to gaze beyond our nose and above our shoulders into the immensity of being, it is likely that we come at last to the conviction that there is an infinity of ever new worlds, as Giordano Bruno once said (and died for it).