10 GENERALIZATIONS: FROM QUANTUM MECHANICS TO GOD

INTRODUCTION: EVOLUTION WITHIN THE CONCEPTUAL FRAMEWORK

The evolution of concepts is a driving force of scientific progress. A new concept contains in itself the heritage of its predecessors and, at the same time, is open to future generalizations. However, concepts never evolve "by themselves"; they participate in the struggle of solving problems. There is always a problem that has to be solved, a challenge to the concept currently in use. If an attempt to put a new content into an old concept produces paradoxes and inconsistencies, one is confronted with a crisis. Many such "critical situations" make the concept less resistant to change, and in this way a "conceptual revolution" is initiated.

In fact, there are no isolated concepts in science. Every change in the content of one concept results in shifts of meaning in many other concepts. It is, therefore, more correct to speak about evolution within the conceptual framework than about the evolution of particular concepts. There are various mechanisms of this evolution—from gradual modifications to sudden jumps. To describe them in particular cases, in as detailed a way as possible, is a task for historians of science, and to reconstruct different patterns of this evolution is a challenge for philosophers of science.

The evolution of concepts is reflected in the evolution of language. Some philosophers are inclined to reduce the evolution of science to the evolution of scientific language. It is usually easier to analyze terms as they appear in various linguistic contexts than to explore the meanings of concepts as they unfold in the historical process of the development of science. However, people engaged in creating science think rather than speak, or first think and then speak to each other; and thinking is in terms of concepts, whereas speaking is in terms of terms. This is why, in the following, I prefer to focus on concepts rather than on terms. The point is, however, that for the analyst the only way to concepts is through their linguistic counterparts, that is, through terms.

Evolution "within the conceptual framework" is especially clearly seen at the extremities of the history of science, that is, in its beginnings and in the current frontier of research. Let us consider an example.

The "great miracle," the origin of rational discourse concerning the world, happened around the sixth century B.C. in the Greek colonies on the coast of Asia Minor. Central to this process was the formation of the concept of necessity. This concept gradually replaced the former idea of the world as a stage of passion and a "free game" between gods or primitive elements. It is necessity that produces the natural order by linking different phenomena into chains of causes and effects. To express this idea the Greek thinkers used the term *ananke,* which in everyday language "literally meant the various means, from persuasion to torture, by which a criminal was made to confess."[1] In this way, the everyday concept changed its meaning to become a predecessor of such important concepts as law of nature, determinism, and causality. In the subsequent history of science these concepts were never static; they underwent many changes and transformations.

Now, let us go to the other extremity of history, to current research in quantum mechanics. The very same concepts—determinism, causality, law, and chance—are at the focus of the contemporary debate. Although all these concepts are outcomes of a long evolutionary chain of various adaptations and mutations, their contemporary meanings are shaped by problems in which they are involved and which remain to be solved. Such problems as "decoherence," "entanglement," "nonlocality" (to name only the most widely discussed) permeate the above-mentioned concepts and change their meanings from inside.

There are many patterns according to which concepts evolve, but in all these "adventures of ideas" one can quite easily discern a certain common feature: as concepts evolve, they become more and more general. The history of physics clearly shows that although the tendency to generalization has seldom been a leading motive for change, the new concepts were usually more general than the old ones. This process is by no means a linear one. It has many side-branches and ramifications. In particular, it may well happen that as time passes some concepts become more refined and more specific. After all, the goal of science is to explain each specific phenomenon, but to explain such a phenomenon means always to place it in a more general pattern. This seems to be consonant with the fact that in the generalization process old concepts are not eliminated but are limited in their validity to a smaller domain than originally

1. O. Pedersen, *The Book of Nature,* Vatican City State: Vatican Observatory Publications, 1992, 8.

envisaged. The point is that it is precisely the tendency toward more and more general horizons that makes the mainstream current in the evolution of science. One could risk the statement that the generalization of concepts and theories determines an "arrow of time" within the process of scientific transformation.

The history of science could be looked upon as a great attempt by humanity to catch reality in the net of concepts and theories. And every time we think the endeavor has succeeded, it turns out that reality is richer than the concepts and theories elaborated so far. The situation is not unlike the one in theology where one speaks about God even if one believes that God is infinite and, consequently, transcends all human conceptual and linguistic possibilities. Some theologians go so far as to say that everything we can assert about God is by negation *(via negativa)*. For instance, if we say that God is infinite, we in fact deny to God the property of being finite—the property which we know from our own experience, and about which we are able to speak sensibly. In the view of many theologians, some other concepts (whose origin is not so manifestly by negation as the concept of infinity), when referred to God, "though partly true, [are] ultimately false and must be transcended."[2] The concept of Being itself would belong to this class, although it was Duns Scotus who claimed that if we say "God exists," there is more falsehood than truth in this statement.

Does this mean that we should remain silent about God? Traditional theology never surrendered to this temptation. It is better to say something about God rather than nothing, even if it is at the cost of transcending the syntactic and semantic rules of ordinary language. Syntactic and semantic rules are indeed at the center of interest in modern analytic philosophy. After the first period of enthusiasm, it soon turned out that the purely formal approach to language was not enough. No language can fulfill its role without an interpretation, that is, without a world of "objects" or "states of affairs" to which it *refers*. The problem of *reference* became the central problem of the philosophy of language. Ludwig Wittgenstein in his *Tractatus Logico-philosophicus* went so far as to ask the question: What structure should be ascribed to the world to ensure the meaningfulness of language? He tried to answer this question in a purely formal way. However, he soon realized that the purely formalistic standpoint is not enough. In his *Philosophical Investigations* he claims that the meaning of a term is determined by the rules of its usage in a given context within a certain "linguistic game." If so, can we meaningfully speak about what goes beyond the domain of our "linguistic games," that is, beyond the domain of our everyday activity? And what about the language of science and philosophy? In both

2. R. C. Neville, *A Theology Primer,* New York: State University of New York Press, 1991, 179.

of these fields we try not only to describe what we see, but also (or even first of all) to understand what cannot be seen (e.g., the subatomic world). Ladrière regards this as a challenge for the "Great European Rationalism."[3]

In contemporary physics we are faced with insistent interpretative problems, focusing on the question of how to correlate our language with what we have been lucky to decipher regarding the quantum world. And this issue of interpretation is even more insistent in theology. It is true that we can speak about God only "on the ruins of our semantics," but I think that from the very fact that our language breaks down, and from trying to see how it does break down, we could be able to say more about God than by simply adding a negation functor to our utterances. In modern physics, the breakdown of language is an unmistakable sign that underlying concepts should be generalized. The assumption underlying the present study is that theology can learn something, in this respect (by analogy rather than in detail), from physics.

Of course, there is one great difference between physics and theology that should constantly be kept in mind. A generalized concept always transcends the concept of which it is a generalization. In physics, we can compare the two concepts with each other, and clearly see the semantic mechanisms that are at work in the generalization process. If this strategy is applied to language about God, we know that our everyday concepts must be transcended; but we can only speculate how this should be, and we will never know to what extent the newly elaborated concepts are adequate. In contemporary physical theories the degree of generalization is immense. Concepts that are now standard in physical theories are very distant from those we use in our everyday life. In theology the degree of transcendence goes much further.

The goal of this chapter is to look, in this respect, at contemporary quantum theory and try to derive from it a lesson for theology. To do so more effectively, in analyzing quantum physics I will use not quite standard (but perfectly legitimate) tools. My starting point is the fact that the main distinguishing feature of quantum mechanics is its noncommutativity (this is, of course, very well known); and to show the degree of generalization already present in this physical theory, I will use the recently discovered noncommutative geometry. It not only clearly shows the generalization mechanisms underlying the present theory; it also points toward its possible further generalizations.

ALGEBRAIC FORMULATION OF QUANTUM MECHANICS

How can we gain access to the quantum world, which, in itself, is closed to our sensory perceptions? We can only hope that some quantum phenomena,

3. J. Ladrière, *L'articulation du sens,* vol. 2, Paris: Éd. CERF, 1984, 109.

after being magnified to the classical level (spontaneously or through our artful inventions), could be detected by some of our measuring devices. Perhaps the fact that this sometimes does happen is not entirely surprising. After all, our macroscopic world has somehow emerged from the more fundamental quantum level. These properties of the quantum world, which can, at least in principle, be measured by our macroscopic devices, are called *observables.* The question that arises is, Can we construct a full theory of the quantum world based only on observables? The question itself and the positive answer to it, favored by some adherents of the so-called Copenhagen interpretation, are evidently philosophical in character. They were prompted by an empiricist presupposition that, in the circumstances, seemed to be entirely reasonable. Historically, of course, this presupposition owed much to the philosophy of logical positivism.

Today we think that the physics of quantum theory can be expressed not only in terms of observables alone (or operators, see below) or of the states of a quantum system alone (or vectors of a Hilbert space), but in ingenious combinations of the two (such as expectation values or transition matrix elements). We can choose as primitive elements of the theory either states or observables. In fact, the empiricist formulation of quantum mechanics based on observables came later, when the formulation in terms of unobservable states (represented as vectors in a Hilbert space) was already well known and thoroughly explored. Of course, what one needs is a certain mathematical representation of observables, but once one has it, the entire range of quantum mechanics can be expressed in terms of this representation. From the works of P. Jordan, J. von Neumann, and E. Wigner,[4] I. E. Segal,[5] and R. Haag and D. Kastler,[6] the formulation of quantum mechanics emerged that is now known as its *algebraic formulation.* One first defines an abstract C*-algebra (read: "C-star-algebra"), and it turns out that its elements can be regarded as mathematical representatives of observables (if there is no danger of misunderstanding, elements of the C*-algebra are also called *observables*). It can be proved that from the C*-algebraic formulation of quantum mechanics, one can recover its original formulation in terms of Hilbert spaces.[7] In fact, the C*-algebraic formulation of quantum mechanics is more general than its Hilbert space formulation, just to the extent needed. Quantum statistical mechanics and quantum systems with

4. P. Jordan, J. von Neumann, and E. Wigner, "On the Algebraic Generalization of the Quantum Mechanical Formalism," *Ann. Math.* 35 (1934) 29.

5. I. E. Segal, "Postulates for General Quantum Mechanics," *Ann. Math.* 48 (1947) 930–948; "Irreducible Representations of Operator Algebras," *Bull. Am. Math. Sic.* 53 (1947) 73–88.

6. R. Haag and D. Kastler, "An Algebraic Approach to Quantum Field Theory," *J. Math. Phys.* 5 (1964) 848–861.

7. See, for instance: W. Thirring, *Lehrbuch der Mathematischen Physik,* Wien: Springer, 1979.

an infinite number of degrees of freedom (field theories) are somewhat beyond the reach of the Hilbert space formulation, whereas the C*-algebraic formulation works in these areas very well. And it came as a nice surprise that, for some time, C*-algebras had been well known to mathematicians. Such algebras naturally appear in the theory of so-called Banach spaces, an important mathematical theory.

Physicists invented the C*-algebraic formulation of quantum mechanics by isolating some properties connected with measuring procedures from the usual Hilbert space formulation of this physical theory. This statement should be understood in the following way. As already mentioned, in the standard formulation vectors in a Hilbert space represent states of the quantum system under consideration. When a measurement is carried out of a quantum system in a given state, the measuring device interacts with this system, changing its state. Therefore, the measurement consists of a transition from one state to another, and the act of measurement is what causes this transition. Because states are vectors in the Hilbert space, formally the measurement should be described as something that, by acting on a vector in the Hilbert space, changes this vector into another vector in the same Hilbert space. Something that does this is known in mathematics as an operator (acting on a given Hilbert space). We can depict this in the following way:

operator: vector 1 ⇒ vector 2

Because various devices measure various physical properties (one measures position, another momentum, etc.), various operators can be identified with various physical properties of quantum systems. This is why operators on a Hilbert space are also called simply *observables,* and, if there is no danger of misunderstanding, the name is used interchangeably for physical properties and operators corresponding to them.

Once we are in the kingdom of mathematics, we can profit from its rich possibilities. For instance, we can use the mathematical concept of representation to understand the connection between the theory of C*-algebras and the theory of Hilbert spaces. To say that an abstract mathematical structure has a representation in a concrete mathematical structure means that the concrete mathematical structure has all the formal properties of the abstract structure—that it is its concrete incarnation. And it is exactly what happens in our case: every C*-algebra has a representation in a subset of (bounded) operators in a Hilbert space. The fact that the set of observables in quantum mechanics has formal properties of a C is not just a happy coincidence; it is rooted in deep mathematical results.

Now, we come to our main topic. C*-algebras that find their application in quantum mechanics, in particular in algebras of (bounded) operators on a Hilbert space, are *noncommutative* algebras. We say that a certain operation, for example, multiplication, is commutative if the order of factors does not affect the result. For instance, $3 \cdot 7 = 7 \cdot 3$, which means that the multiplication of numbers is commutative. If this property does not hold, we say that the operation is *noncommutative,* and in fact the multiplication of operators in a Hilbert space is noncommutative. As we can see, the concept of commutativity is a very simple concept, but it has far-reaching consequences. I would risk the statement that (besides linearity) it is precisely the noncommutativity of observables in quantum mechanics that is responsible for all the peculiarities of this physical theory. Let us consider an example.

For a newcomer into the field of quantum mechanics, the Heisenberg relations are always a great surprise. It turns out that they are the direct consequence of noncommutativity. Let, for instance, x be the position of a particle and p its momentum. If they multiply in the commutative way (as it is the case in classical physics), we would have

$$xp = px$$

or

$$xp - px = 0.$$

But in quantum mechanics we have

$$xp - px \neq 0,$$

and indeed this difference cannot be less than the Planck constant h, that is,

$$xp - px \geq h.$$

This is exactly the Heisenberg relation for the position and momentum. It can be interpreted in the following way. If we first measure the momentum of a particle and then its position (first p then x, we write it in the reverse order as xp), the measurement of momentum perturbs the position of the particle, and consequently the result is different from when we first measure the position of a particle and then its momentum (px) because in the latter case the measurement of the position disturbs the momentum of the particle (consequently, $xp \neq px$). And it is the Planck constant h that determines the lower bound of this perturbation.

It is a custom in mathematics to abbreviate the expression $xp - px$ to $[x, p]$ and to call it the *commutator* of x and p. Therefore, if x and p are the position and momentum of a classical particle, for example, of a billiard ball, we can write

$$[x, p] = 0;$$

and if x and p are the position and momentum of a quantum particle, we have

$$[x, p] \geq h.$$

Let A be a C*-algebra. If it is a commutative algebra, the commutators of all its elements vanish, that is,

$$[a, b] = 0,$$

where a and b are any elements of A. If A is a noncommutative algebra, the commutators of at least some of its elements, for instance, of a and b, do not vanish, that is,

$$[a, b] \geq k,$$

where k is a deformation parameter. Every commutative algebra can be made noncommutative by suitably perturbing it (with a certain perturbation parameter). In the light of the above we can say that, from the mathematical point of view, quantum mechanics is but a noncommutative C*-algebra, with the Planck constant playing the role of a deformation parameter. In fact, it must be assumed that the deformation parameter is only related to the Planck constant.

In the next section we will explore some important consequences of noncommutativity more deeply.

ONE STEP FURTHER

One of the main trends in modern physics is the tendency to geometrization. It can be traced back to Descartes, who claimed that extension (which is a purely geometric property) is the fundamental property of material bodies and, consequently, that physics should be carried on *more geometrico.* This tendency reached its peak with Einstein's general relativity, which is par excellence a geometric theory; its main idea is to present gravity as the curvature of space-time. On the other hand, quantum mechanics could hardly be called a geometric theory. Its strongly probabilistic features make it rather far away from anything we would be inclined to associate with geometry. This is certainly one of the reasons why it is so difficult to unify quantum mechanics with general relativity. However, we could at least try to look at quantum mechanics with a "geometric eye" and to geometrize at least some of its aspects.

It is rather evident that in this process the very concept of geometry would have to be generalized. It often happens that if a mathematical or physical theory admits more than one formulation, only one of these formulations can serve as a suitable starting point for the chain of subsequent generalizations. It turns out that in the case of quantum mechanics this role is fulfilled by its algebraic formulation (briefly presented in the preceding section) rather than by its usual formulation in terms of Hilbert space. To show this we must first turn to the very concept of geometric space.

In modern differential geometry, the concept of geometric space has been rigorously elaborated and is known under the technical term of "differential manifold" or simply "manifold." The standard way of defining this concept is in terms of coordinate systems with which this "space" can be equipped. This way of defining a manifold closely follows the practice of geometers who usually do their calculations in terms of coordinates of various geometric objects (points, vectors, curves) in a given manifold. It turns out, however, that this approach is rather rigid, not suitable for further generalizations. Happily enough, there is another equivalent method of defining a manifold that proves to be more flexible in this respect. Instead of considering coordinate systems on a given manifold, we can consider a family of all smooth functions on this manifold, and it can be shown that all relevant information about the manifold is contained in this family of functions. The essential point is that it forms an algebra. In principle, one can forget about coordinates and construct the geometry of the manifold entirely in terms of the algebra of smooth functions. To deal with functions is usually more difficult than to compute with the help of coordinates, but, as we have remarked above, the "functional" approach turns out to be more suitable for further generalization.

First, we can take any algebra of functions and treat it—*ex definitione*—as consisting of smooth functions on a certain space. Spaces that are introduced in this way are called *differential spaces* (or *structured spaces*), and they are more general than differential manifolds: each manifold is a differential space, but not every differential space is a manifold.[8]

Because functions are multiplied in a commutative way, all functional algebras (i.e., algebras the elements of which are functions) are commutative algebras, but we can go even further and claim that any algebra, not necessarily a commutative one, defines a certain space. In such a case, we speak about a *non-*

8. See M. Heller and W. Sasin, "Structured Spaces and Their Application to Relativistic Physics," *J. Math. Phys.* 36 (1995) 3644–3662. Structured spaces are somewhat more general than differential spaces.

commutative space. This is the main idea of the new branch of mathematics that is nowadays known under the name of *noncommutative geometry.* It has recently been elaborated, in great detail, by many mathematicians and theoretical physicists.[9]

POINTLESS SPACES

Noncommutative geometry is indeed a vast generalization of the standard geometry. Some "sets" or "objects," which did not surrender so far to the usual geometric methods and were regarded as pathologies rather than mathematically described "sets" or "objects," are now perfectly workable noncommutative spaces. One of the main peculiarities of noncommutative spaces is their totally global character. In principle, no local concept can be given any meaning in the context of noncommutative geometry. Typical examples of local concepts are those of point and neighborhood, and it turns out that, in general, we cannot say that a noncommutative space consists of points. Noncommutative spaces are indeed pointless spaces. Let us look more deeply into this matter.

As we know, noncommutative geometry is based on algebraic concepts, and if we want to reach the very roots of the point concept we should think in algebraic terms. In the standard approach, points of any differential manifold (which is a commutative space) are identified with the help of their coordinates, but how can one identify a point when one works with the algebra of smooth functions on a given manifold rather than with coordinate systems on it? The answer is quite straightforward. It is clear that every point is uniquely determined by all smooth functions that vanish at it. The family of such functions has certain properties that—in mathematical jargon—qualify them as *maximal ideals* of the algebra of smooth functions on the manifold under consideration. We can say that in the algebraic approach, the role of points is played by maximal ideals of a given algebra. In other words, in the standard (commutative) geometry, a point can be equivalently described either by specifying its coordinates (in a given coordinate system) or as a maximal ideal of the algebra of smooth functions on the manifold (space) under consideration. And here we touch on an important property of noncommutative algebras: in general, they have no maximal ideals, and consequently it is impossible to define points in noncommutative spaces. Similar reasoning shows also

9. See, for instance: A. Connes, *Noncommutative Geometry,* New York and London: Academic Press, 1994; G. Landi, *An Introduction to Noncommutative Spaces and Their Geometries,* Berlin, Heidelberg, and New York: Springer, 1997; J. Madore, *An Introduction to Noncommutative Differential Geometry and Its Physical Applications,* 2nd ed., Cambridge: Cambridge University Press, 1999.

that the concept of a neighborhood (of a given point) is meaningless in them.

To see the vastness of the generalization encountered here, let us look at this problem from yet another point of view. It is sometimes claimed that set theory can serve as a logical basis for all other mathematical theories. Of course, the crucial concept in set theory is that of "belonging to a set." For this concept to have a meaning, one must be able to identify elements of the collection under consideration by means of an at most denumerable family of properties. In noncommutative spaces, in general, there is no such possibility; one cannot distinguish the elements of such a collection from each other by means of a denumerable family of properties. (Each such property would define a measurable subset of the collection being considered.[10]) Alain Connes concludes: "The noncommutative sets are thus characterized by the effective indiscernability of their elements."[11]

The concept that is closest in this context to the concept of point is that of state. It is well known in both classical and quantum physics. Let us note, however, that it is a global concept. For instance, in classical mechanics the state of a system composed of n particles, where n can be as large a number as one wishes, is characterized by providing information about the positions and momenta of *all* particles. In quantum mechanics, states are represented by vectors in a Hilbert space and play the crucial role in the structure of this theory. The nonlocal character of this concept can be clearly seen, for instance, in the Einstein-Podolsky-Rosen-type experiments, in which two particles (e.g., electrons) that once interacted are described by the same state (or by a vector in a Hilbert space), even if they are now at opposite edges of the Galaxy.

We can now quite clearly see that there is a certain affinity between the main characteristic of quantum mechanics and that of noncommutative geometry. It looks as if a noncommutative space were underlying quantum phenomena. The Heisenberg relations, nonlocal effects, and the importance of the state concept are doubtlessly results of some underlying noncommutativity. As we remember from section 2, quantum mechanics can be expressed in terms of a noncommutative C^*-algebra, and it is a straightforward thing to associate with such an algebra a noncommutative space. However, we will not pursue this line of research. Ambitions of physicists go much further than to obtain yet another formulation of that well-known theory. The main goal of current research in theoretical physics is to unify quantum mechanics with general relativity, and it seems that noncommutative geometry can offer new possibilities

10. This is valid provided one decides to use only measurable maps between spaces; see A. Connes, *Noncommutative Geometry,* 74.

11. Ibid.

here. In fact, there have been many attempts to formulate a noncommutative version of general relativity with the clear intention of making it later a quantum gravity theory.[12] In a series of papers, I have presented, together with my coworkers, a working model of how this could be done.[13] This is certainly not yet a full physical theory, but rather an attempt to find a new pathway that would possibly lead to the main goal of current investigations in physics. The first results are encouraging, but there is still a long way to go. In this study, I will not go into details of this approach but rather will sketch the philosophy underlying the project. In this chapter, I am interested not so much in physical results as in the "adventures of concepts" and in what can be learned from physical models about the limits of language and imagination.

NONCOMMUTATIVE REGIME

The main idea of the new approach is to suppose that the physics ruling the Universe on the fundamental level is based on a noncommutative geometry, and that on this level there is no distinction between physical processes and the (spatio-temporal) stage on which they develop. There is instead a nonlocal (noncommutative) "pregeometry" that encompasses everything. Only when we go from the fundamental level to the upper layers of the world's structure does the distinction between the spatio-temporal arena (governed by the ordinary, commutative geometry) and physical processes emerge. By the fundamental level we mean everything that happens below the Planck threshold. This threshold is encountered in two directions: first, if one goes *backward in time* until one reaches the moment at which the typical dimension of the Universe was of the order of 10^{-33} cm (the so-called *Planck length*); second, if one goes *now* to smaller and smaller distances until one reaches the distance 10^{-33} cm. Because below the Planck threshold there is no space and time, in the usual meaning of these terms, these two directions coincide in fact.[14]

12. See, for instance: A. H. Chamseddine, G. Felder, and J. Frölich, "Gravity in Non-Commutative Geometry," *Commun. Math. Phys.* 155 (1993) 205–217; A. H. Chamseddine and A. Connes, "Universal Formula for Noncommutative Geometry Actions: Unification of Gravity and the Standard Model," *Phys. Rev. Lett.* 24 (1996) 4868–4871; J. Madore and J. Mourad, "Quantum Space-Time and Classical Gravity," *J. Math. Phys.* 39 (1998) 4423–4442.

13. M. Heller, W. Sasin, and D. Lambert, "Groupoid Approach to Noncommutative Quantization of Gravity," *J. Math. Phys.* 38 (1997) 5840–5853; M. Heller and W. Sasin, "Emergence of Time," *Phys. Lett.* A250 (1998) 48–54; M. Heller and W. Sasin, "Noncommutative Unification of General Relativity and Quantum Mechanics," *Int. J. Theor. Phys.* 38 (1999) 1619–1642; M. Heller, W. Sasin, and Z. Odrzygóźdź, "State Vector Reduction as a Shadow of Noncommutative Dynamics," *J. Math. Phys.* 41 (2000) 5168–5179.

14. The Planck threshold is also characterized by other magnitudes: the *Planck time* equals 10^{-44} seconds, and the *Planck density* equals 10^{95} g/cm^3.

This idea did not appear from nothing; it was suggested by our work on classical singularities.[15] Roughly speaking, the (initial) singularity is a geometric counterpart of the Big Bang, and "classical" means that when investigating it we do not take into account quantum effects. To decipher the geometric structure of the Big Bang, we have used the methods of noncommutative geometry that turn out to be very effective in this respect. Our result was that at the level described by noncommutative geometry there is no space-time and no distinction between singular and nonsingular states. Both space-time and singularities appear as soon as we change to the usual, commutative description. Moreover, some mathematical techniques (operators on a Hilbert space) typical for quantum mechanics appear almost automatically. It was quite natural to take one further step and to speculate that these features are not just interesting coincidences. Rather, they indicate that the fundamental level is indeed noncommutative.

Let us describe, in a more detailed way, what the noncommutative regime of the fundamental level might look like. The most striking feature of this regime is its entirely nonlocal character. This creates also the main difficulty we encounter in thinking about it, because all our thinking takes place in local terms (I am a localized individual at a concrete place and in a concrete instant of time). Happily enough, the language of mathematics transcends the reach of imagination and gives us some insights into the realms of noncommutativity.

In the noncommutative regime, there is no time and no space with their accompanying concepts of point and time-instant. Does this mean that there is no motion and dynamics? Certainly! Without the usual concepts of space and time one cannot have the usual concept of motion. But this does not mean that there can be no dynamics in an admittedly generalized sense. Usually, dynamical magnitudes (such as velocity and momentum) are described by vectors that, as local concepts, do not appear in a noncommutative setting. But the idea of a vector field evidently has a global aspect (e.g., a vector field can be defined on an entire space), and as such it has its counterpart in noncommutative geometry. This counterpart is constituted by the so-called *derivation* of a given algebra. Such a derivation transforms one element of the algebra into another element of the same algebra (it therefore models a certain change in the system) and satisfies axioms typical for a vector field.[16] It turns out that it is possible to write down dynamical equations in terms of derivations. Although there is no

15. M. Heller and W. Sasin, "Noncommutative Structure of Singularities in General Relativity," *J. Math. Phys.* 37 (1996) 5665–5671; "Origin of Classical Singularities," *Gen. Relat. Grav.* 31 (1999) 555–570.

16. Linearity and the Leibniz rule.

space and no time, there can be an authentic (albeit generalized) dynamics (see below, subsection 7.2). This falsifies the claim of some philosophers and theologians that in the absence of time one is of necessity confronted with a purely inactive, static situation.[17]

As was mentioned above, one can meaningfully speak about states of the noncommutative Universe. And, as our model shows, all such states are on an equal footing; there is no distinction between singular and nonsingular states. Therefore, the very idea of the beginning of the Universe has to change its meaning radically. If there is no time, one cannot speak about a temporal beginning. This does not necessarily mean, however, that the idea of a "quantum tunneling out of nothing" could not be adapted to the noncommutative conceptual framework.

One of the central concepts of Western philosophy is that of the individual. This concept preserves its importance in classical physics; but already in quantum mechanics, and especially in quantum field theories, very serious difficulties connected with this concept appear.[18] If our hypothetical model is at least approximately true, these difficulties are but the remnants of the totally global character of the noncommutative stage.

We should mention yet another concept that in the noncommutative regime is highly generalized—the concept of probability. Standard probabilistic concepts come into play only when there are many individuals of a certain type. It seems that in quantum mechanics one can apply certain probabilistic concepts even to a single particle. In the noncommutative setting there are no individuals, but nevertheless the probability concept (in a generalized sense) survives.[19] This concept has very little in common with the idea of "counting the ratio of the frequency of favorable events to all possible events," although it reproduces this idea in the correct (commutative) limit. It preserves more abstract properties of the probability concept (such as that the outcome of probabilistic calculations must be always positive and not greater than one). The probabilistic character of quantum mechanics, together with all its probabilistic peculiarities, seems to be but the consequence of the deeper and more general concept of probability permeating the entire noncommutative regime. We will come back to this issue in subsection 7.2.

17. See, for instance, P. Tillich, *Systematic Theology,* London: SCM: 1978, 305; K. Barth, *Dogmatica ecclesiale,* Bologna: Il Mulino, 1968.

18. See, for instance, P. Teller, *An Interpretative Introduction to Quantum Field Theory,* Princeton: Princeton University Press, 1995, chs. 2 and 3.

19. The noncommutative counterparts of the concept of probability are the so-called von Neumann algebras.

EMERGENCE OF STANDARD PHYSICS

Of course, every scientifically valuable model of the pre-Planck era must reproduce the standard physics of the post-Planck Universe. This can be achieved quite naturally in our approach. A center of a noncommutative algebra is the set of all its elements that commute with all other elements of this algebra (i.e., the set of all elements of the algebra that multiply with all other of its elements in a commutative way). If we restrict the original noncommutative algebra to its center (or to a subset of the center), we recover an ordinary commutative algebra. This happens in our model.[20] In this way, we recover the usual physics with general relativity presenting gravity as the space-time curvature, and quantum mechanics as a probabilistic theory. This restriction of the original algebra to its subset can be interpreted as the first "phase transition" in the history of the Universe that gave birth to space, time, and multiplicity.

It is interesting that the detailed analysis of this "phase transition" shows that, together with space-time, classical singularities are born.[21] The situation is the following. From the point of view of an observer situated on the fundamental level (if there could be any), the Universe has no temporal beginning (all its states are on an equal footing), but a macroscopic observer can truly say that the Universe had a temporal beginning in its finite past (the initial singularity) and will possibly have an end in its finite future (the final singularity, if the Universe is spatially closed). This is a new possibility, one that has so far never been considered in cosmology. Until now people have envisaged two mutually exclusive possibilities: either the future quantum gravity theory will remove singularities from our picture of the world, or not. Now, a third possibility appears: singularities are but a part of our macroscopic perspective; regarded from the fundamental level, the question of the existence or nonexistence of singularities is meaningless.

By restricting the original noncommutative algebra to its center, we obtain ordinary physics, but not only that—we obtain something more. In "ordinary physics" there are certain phenomena of typically nonlocal character that either remain unexplained or require some additional (and very often artificial) hypotheses to explain them. Let us mention the Einstein-Podolsky-Rosen (EPR) type of experiments in quantum mechanics in which spacelike separated particles that once interacted "know about" each other, although there is no physical signal with the help of which they could communicate. To explain such phenomena, some exotic interpretations of quantum mechanics have

20. See footnote 13.

21. See our work "Origin of Classical Singularities" quoted in footnote 15.

been proposed. Another typically nonlocal phenomenon appears in cosmology as the so-called horizon problem—how parts of the Universe now far distant from one another that have never been in causal contact with one another can be characterized by exactly the same values of certain parameters (e.g., temperature corresponding to the microwave background radiation). This phenomenon is usually explained by the so-called inflationary model, which is an extracosmological hypothesis (one, by the way, to which some cosmologists strongly object).

All these nonlocal phenomena find their natural explanation within the noncommutative approach. Because the fundamental level is totally nonlocal, it is no wonder that some quantum phenomena (such as the EPR type of experiment) that are rooted in that level exhibit some nonlocal effects; they are but the tip of the iceberg of the "fundamental noncommutativity" that somehow survived the "phase transition" to the usual physics.[22] To explain the horizon problem, we should adopt another perspective and regard the "fundamental noncommutativity" as situated "in the beginning," in the pre-Planck epoch. According to our hypothesis, this epoch was totally global; no wonder, therefore, that when the Universe was passing through the Planck threshold, it preserved some global characteristics also at those places that never (after the Planck threshold) causally interacted with each other.

As I have mentioned, in spite of the fact that the noncommutative regime is timeless, it admits a generalized "global dynamics." In one of our works,[23] the equation describing such a dynamics has been proposed. Our model has (as it should) two "limiting cases": to general relativity and to quantum mechanics. It turns out that, when one goes to quantum mechanics, the noncommutative dynamics leads to the (unitary) evolution described by the Schrödinger equation. If one goes to general relativity, the noncommutative dynamics "projects down" to a process occurring in space-time that can be interpreted as the act of quantum measurement in which the so-called reduction of the state vector takes place.[24] This confirms the opinion, long defended by

22. To see why certain nonlocal effects survive the Planck threshold and can be observed, one should look at some mathematical properties of the noncommutative regime. Generally speaking, the transition from the noncommutative level to the ordinary physics in our model has the character of a projection. Such a projection, being always "onto," switches off all possible "short-distance correlations," but can leave "long-distance correlations." See, for instance, M. Heller and W. Sasin, "Einstein-Podolski-Rosen Experiment from Noncommutative Quantum Gravity," in *Particles, Fields and Gravitation,* ed. Jakub Rembieliński, Woodbury, New York: American Institute of Physics, 1998, 234–241; or M. Heller and W. Sasin, "Noncommutative Unification of General Relativity and Quantum Mechanics," sections 7 and 8.

23. See M. Heller and W. Sasin, "Emergence of Time."

24. M. Heller, W. Sasin, and Z. Odrzygóźdź, "State Vector Reduction as a Shadow of a Noncommutative Dynamics."

Roger Penrose,[25] that it is quantum gravity that is responsible for the phenomenon of the vector state reduction.

Although all the above effects seem to corroborate the idea of a "noncommutative fundamental level," I should stress once more that in this present chapter I am not so much interested in developing a noncommutative "final theory," but rather in treating this possibility as illustrating the "adventures of concepts" in modern physics.

ADVENTURES OF CONCEPTS

Quite independent of whether the hypothesis proposed by us about a noncommutative origin of the Universe is true or not, we can learn a lesson from it. Many important concepts involved in current scientific (and philosophical) research appear in the noncommutative context in a strongly generalized form. I do not claim that when we refer our everyday concepts to God, we should generalize them in a similar manner. My intention is to learn the way in which a concept can be generalized and to treat this as a warning for our theological discourse. Roughly speaking, if such drastic generalization of meanings is possible in physics, how much (infinitely!) more can this occur when we are speaking or thinking about God!

In the following, I will analyze a few concepts that are of great importance for philosophy and theology (such as causality, probability, and dynamics), when they are transferred from their usual context to the environment of the "noncommutative world." This world is powerfully shaped by its two principal (and mutually interconnected) properties: timelessness and nonlocality. Therefore, if we want to obtain "noncommutative counterparts" of the above-mentioned concepts, we must, first of all, strip them of their usual involvement with time and locality. Happily enough, in doing so we are not condemned to work only with the help of our intuition; we can also be guided by strict mathematical methods that securely lead from our well-behaved commutative world into the regions of noncommutativity.

Causality

The problem of causality is difficult even in the commutative world. I do not intend to go into all its subtleties; I will confine myself rather to its most common sense aspects. It seems obvious that causation presupposes distinct events.

25. See, for instance, R. Penrose, *The Emperor's New Mind,* New York and Oxford: Oxford University Press, 1989.

If *a* causes *b,* then *a* and *b* are distinct—that is, they are not identical and neither is a part of the other. The lightning and the thunder are distinct, and this is why it is possible for the lightning to cause the thunder.[26]

How is one to imagine causation in a totally global setting where no well-localized entities can exist?

It seems that causality presupposes a temporal order: causes usually precede their effects. As is well known, there were attempts to reduce causality to temporal sequences. According to Hume (and many of his followers), we cannot know that *"b propter a,"* but only that *"b post a."* What does remain of causality if we strip it from all temporal aspects?

We can, at least partially, answer these questions if we remain in the domain of mathematical models. Space-time in general relativity is equipped with what is called its *causal structure.* This structure is defined by the so-called *Lorentz metric,* which at each point of space-time introduces a light-cone determining how physical signals (or causal influences) can propagate throughout space-time. Every such cone is generated by light-rays emanating from a given point in space-time. No physical signal can propagate outside the light-cone which is equivalent to the fact that the velocity of light is the maximal physical velocity in nature. In this sense, the light-cone structure in space-time determines a "net of channels" through which causal influences can propagate.

When we change to a noncommutative setting, the causal structure drastically alters. First, space-time, as a set of well-localized points and their neighborhoods, disappears, and we are left with a "global" entity that can be in various states. In Connes' approach,[27] so far one has been unable to define a Lorentz metric, only a *Riemann metric.* The latter opens up light-cones in such a way that there is no limiting velocity imposed on physical signal propagation; everything in space-time can be causally connected with everything. However, by using the Riemann metric, one can define the distance between various states. It seems, therefore, that there are states that can be causally connected. In our approach,[28] one can define a Lorentz metric that, however, is totally nonlocal, in the sense that it does not define local light-cones but specifies which vector fields (regarded as global objects) can influence each other. Let us remember that derivations of a given algebra are noncommutative counterparts of vector fields, and, in our model, they are responsible for the dynamics

26. J-M. Kuczynski, "A Solution of the Paradox of Causation," *Philosophy in Science* 8 (1999) 81.
27. A. Connes, *Noncommutative Geometry,* chapter 6.
28. See our works quoted in footnote 13.

of the system. Therefore, we are entitled to say that, in this model, causality is incorporated into its noncommutative dynamics.

The general conclusion of this subsection is that it is possible to generalize the concept of causality so as to free it from the involvement in time and locality. What remains still deserves the name of (generalized) causality because it gives rise to the dynamics of the system. It seems that the essence of causality is a dynamical nexus rather than the distinctness of the cause and its effect, and their temporal order.[29]

Probability and Dynamics

The standard concept of probability also requires well-defined individual events, the probability of whose occurrence is to be computed. On the set of all such events, the so-called *distribution function* is defined, which to every event ascribes a real number from the interval [0, 1]. The *probability* of a given event is the value of the distribution function at this event. Additionally, one assumes that the sum of the probabilities of all events is equal to one (one of the events must occur). The latter assumption is often expressed by saying that probability is "normed to one." In the standard example of throwing dice we have six (elementary) events, and the distribution function for each of them ascribes the real number one-sixth. The sum of these numbers, for all events, is evidently one. The concept of probability in the above sense is a special instance of a more general concept, namely, that of measure, and the theory of probability is but a subchapter of mathematical measure theory. Measure in a generalized sense is a function on a family of subsets *(measurable subsets)* of a certain space *(measure space);* one assumes that values of this function must be positive numbers (including zero and plus infinity) without necessarily assuming that this function is "normed to one."

How can the idea of probability be transferred to the noncommutative environment where all concepts presupposing locality and individuality are in principle meaningless? It cannot be simply transferred but can be generalized, and a hint of how to do this is contained in the fact that the concept of probability is strictly connected with the concept of function (the distribution function). We cannot go into details here; let us mention only that the concept of measure finds its generalized counterpart in the so-called *von Neumann algebras.* Von Neumann algebra is, roughly speaking, a $C^\star$-algebra (see section 2) with a certain positive functional that is "normed to one" (such a functional is called a

29. This conclusion is consonant with the traditional pre-Humean notion of causality as linked primarily to agency and not to time-order.

state).[30] The concept of functional generalizes the concept of function,[31] and the fact that it is positive and "normed to one" is a trace of an affinity of this concept with the usual concept of probability.

Happily enough, the concept of generalized probability in the noncommutative regime is strictly connected with another important property: von Neumann algebras are "dynamical objects." In section 5, we said that in the noncommutative regime, a generalized dynamics can be constructed in terms of derivations of a given algebra, but if the algebra in question is a von Neumann algebra the dynamics significantly improves. On the strength of the famous Tomita-Takesaki theorem,[32] von Neumann algebras guarantee the existence of a certain parameter[33] which "imitates time" and in terms of which we can write generalized dynamical equations.[34] It is not yet the "true time," because it depends on the state of a physical system. In each state we have an essentially different "flow of time" with no possibility of synchronizing them! But we can write truly dynamical equations with the above parameter playing the role of the independent variable.

It is a remarkable fact that in von Neumann algebras the concepts of generalized probability and generalized dynamics are unified. We know from quantum mechanics that quantum systems evolve in a probabilistic manner. The dynamical equation, which in the case of quantum mechanics is the Schrödinger equation, does not describe the evolution of an elementary particle (e.g., of an electron), but rather the evolution of probabilities with which we ascribe certain properties (e.g., position or spin) to something we call an elementary particle. Let us notice that these evolving probabilities have a nonlocal character. It is just because of this nonlocal character that the act of measurement of a certain quantum property (e.g., of spin) performed at a particular location can affect an act of measurement separated from that location by a spacelike interval, that is, an interval that could be covered only by a superluminal signal. We could regard this peculiarity as a trace or a remnant of the noncommutative, totally nonlocal, fundamental level.

Probability, as we know it from standard mathematical measure theory or

30. For a precise definition, see, for instance: V. S. Sunder, *An Invitation to von Neumann Algebras,* New York and Berlin: Springer, 1986.

31. Roughly speaking, functional is a "function on functions."

32. The Tomita-Takesaki theorem essentially says that if A is a von Neumann algebra, then there exist mappings $a_t : A \to A$ forming one-parameter groups, called *modular groups,* which are dependent on the state of the algebra A (see V. S. Sunder, op. cit., ch. 2). These one-parameter groups can be used to parametrize the dynamics.

33. Strictly speaking, the existence of one-parameter groups.

34. See M. Heller and W. Sasin, "Emergence of Time."

from its quantum mechanical version, could be but a shadow of the noncommutative properties of the fundamental level encoded in a von Neumann algebra.

Finally, let us go back to the issue of time. With our von Neumann algebra *A* there is associated a group, called a *unitary group.* In terms of this group we can define a certain condition (called *inner equivalence*), and if the algebra *A* satisfies this condition (which glues together some elements of the algebra *A*, making it "coarser"), all state-dependent times can be synchronized to obtain the single "unitary" flow of time. We recognize in it the same time that measures the unitary evolution of observables in the usual quantum mechanics. However, only if the algebra *A* is restricted to its center does one recover the familiar macroscopic time. It seems, therefore, that the "emergence of time" is a gradual process that can be mathematically modeled.[35]

THEOLOGICAL CONSEQUENCES

The Primary Cause

As is well known, traditional philosophy and theology identified God with the Primary Cause. Although philosophical and theological texts were full of declarations that in this context causality should be understood in an analogous manner, it seems that in practice this concept was treated much more univocally than other concepts referred to God. The very distinction between the Primary Cause and secondary causes is based on everyday experience that teaches us "that individual things have their own operations, through which they are proximate causes of things, not of all things but only of some,"[36] and our own operations are so overwhelmingly causality-laden that we subconsciously attribute the same to God.

With the advent of modern science, the tendency arose to narrow the concept of causality only to efficient causality, and the great influence of Cartesian philosophy added to this concept an intuition of a direct contact between the cause and its effect. These ideas concerning causality were strengthened and consolidated by the progress brought about by Newtonian mechanics, although this branch of physics, with its *actio in distans* and its principle of extremal action (discovered soon after), was rather far from such simplistic

35. Details can be found in: M. Heller and W. Sasin, "Emergence of Time"; see also A. Connes and C. Rovelli, "Von Neumann Algebra Automorphisms and Time-Thermodynamics Relation in Generally Covariant Quantum Theories," *Class. Quantum Grav.* 11 (1994) 2899–2917.

36. St. Thomas Aquinas, *Scriptum super libros Sententiarum Petri Lombardi,* Book 2, Distinction 1. Question 1, Article. 4; English translation: *Aquinas on Creation,* trans. S. E. Baldner and W. E. Carroll, Toronto: Pontifical Institute of Medieval Studies, 1997, 83.

ideas.[37] In our time, quantum mechanics has virtually put an end to mechanistic and deterministic interpretations of the causal nexus, but some other forms of causality are in circulation.[38] So-called "bottom-up" causation exhibits a strong reductionist flavor, at least if the reductionism is understood in Steven Weinberg's sense of "petty reductionism," when a whole system, its structure and functioning, is regarded as arising from the sum of its constituent units, their properties, and their behavior.[39] This type of causation is often correlated with (not necessarily opposed to) "top-down" causation. The latter was first recognized in nonlinear dissipative systems in which

> the changes at the microlevel, that of the constituent units, are what they are because of their incorporation into the system as a whole, which is exerting specific constraints on its units, making them behave otherwise than they would in isolation.[40]

It was soon extended beyond its original domain to denote something "more open and more non-local than that."[41]

It might seem that the causality encountered in noncommutative models (as it was discussed in subsection 7.1) is a kind of "top-down" causality. However, if we take into account the fact that, according to these models, this type of causality operates at the most fundamental level, it could almost equally well be called "bottom-up" causality. I think that its distinctive feature is not its "vertical" operation mode, but rather its atemporal and nonlocal behavior. And if we could learn from it something about God's possible ways of acting in the world, it would reveal first of all the drastic difference between this type

37. Newton himself was much subtler in his understanding of causality than many of his followers. At the end of his *Principia,* in the General Scholium, he wrote: "Hitherto we have explained the phenomena of the heavens and of our sea by the power of gravity, but have not yet assigned the cause of this power. This is certain, that it must proceed from a cause that penetrates to the very centres of the sun and planets, without suffering the least diminution of its force; that operates not according to the quantity of the surfaces of the particles upon which it acts (as mechanical causes used to do), but according to the quantity of the solid matter which they contain, and propagates its virtue on all sides to immense distances, decreasing always as the inverse square of the distances" (*Principia,* vol. II, trans. F. Cajori, Berkeley: University of California Press, 1962, 546).

38. In these forms of causality "the same cause is always followed by the same effect" does not necessarily hold.

39. S. Weinberg, "Reductionist Redux," *The New York Review,* (5 October 1995) 39–42.

40. A. Peacocke, "God's Interaction with the World—The Implications of Deterministic 'Chaos' and of Interconnected and Interdependent Complexity," in *Chaos and Complexity,* R. J. Russell and A. Peacocke, eds., Vatican City State: Vatican Observatory Publications; Berkeley: The Center for Theology and the Natural Sciences, 1995, 273.

41. J. Polkinghorne, "The Metaphysics of Divine Action," in *Chaos and Complexity,* 151. The problem of the "top-down" causation, referred to God's action in the world, was extensively discussed in the volume *Chaos and Complexity* in the present series of the Vatican–CTNS conferences; see papers by Arthur Peacocke, John Polkinghorne, Willem Drees, and William Stoeger.

of causality and what we would traditionally qualify as causality. I think, however, that in spite of this difference, the former deserves the name "causality." This terminological decision is justified by the fact that noncommutative causal structure (in the mathematical sense) is a legitimate generalization of the usual causal structure of space-time studied in general relativity. I by no means want to say that when speaking about God's causality we must regard it as a sort of noncommutative causality; I want only to emphasize that we must treat the doctrine of the analogous or metaphoric character of theological language more seriously.

We think about God as the Primary Cause because we regard the world (both in its entirety and in its details) as an effect of God's action. This causal nexus between God and the world is called *creation.* And it is precisely at this point that we must revise our theological concepts. In the light of the above analysis, we should take into account the possibility that the concept of causality does not necessarily presuppose a local interaction between the cause and its effect *(global aspect of causality),* and that it does not necessarily include a temporal order *(atemporal aspect of causality).* Let us notice that the time-honored metaphysical question (so persistently asked by Leibniz) "Why is there something rather than nothing?" has a strong globally causal flavor. By asking this question we do not restrict the world's existence (which we want to justify) to any particular place or time-instant. And the possibility, very seriously considered by St. Thomas Aquinas, that the world could exist from eternity and nevertheless be created by God, emphasizes an atemporal aspect of God's causality. It is truly worthwhile to read old masters from the perspective of the most recent scientific theories! The point is, however, that one should not repeat their doctrines blindly but look at them with an eye sharpened by the enlargements of imagination prompted by the achievements of modern science.[42]

Ernan McMullin in his recent study[43] takes over the traditional doctrine of creation. Alluding to St. Augustine's view, he contemplates the "Creator in the fullest sense," a "Being from whom the existence of all things derives" (p. 104). Such a Being cannot be subject to any constraints, and temporality is certainly a severe constraint.

> Time is a condition of the creature, a sign of dependence. . . . The act of creation is a single one, in which what is past, present or future from the perspective of the creature issues as a single whole from the Creator. (p. 105)

42. See Chapter 9.

43. E. McMullin, "Evolutionary Contingency and Cosmic Purpose," *Studies in Science and Theology* 5 (1997) 91–112. In the following, numbers in parentheses refer to the pagination of this paper.

In this sense, the Creator is "outside" the transient passage of time. Of course, it is only a metaphor but an important one. If we enrich it with Boethius' famous definition of eternity as "the whole, simultaneous and perfect possession of boundless life,"[44] it conveys not so much an image of timelessness, as of fullness of time.

The concept of existence is crucial for the traditional creation doctrine. However, it is notoriously vague and fuzzy.[45] In contrast with the concept of atemporality, one can hardly find in contemporary physics anything that would help one to understand better the meaning of "existence." Perhaps the only hint that the process of physicalization can one day embrace the idea of existence is the dispute in the conceptual foundations of quantum field theories concerning the identity of elementary particles.[46] The discovery that they are lacking what could be termed "primitive thisness"[47] is at least a signal that the problem of *modus existendi* could have a physical component.

Chance and Purpose

We usually think about chance and purpose in terms of probabilities. For instance, if an event of very small probability happens, we say that it has either happened by chance or has been purposefully chosen by an intelligent agent. We claim that, given a long enough span of time, even events of the slightest probability will be realized. If this type of argument is applied to the Universe as a whole, it often assumes the form of various teleological or antiteleological disputes. All of them tacitly assume that the "classical concept of probability" is valid on all levels of reality. As we have seen above (see subsection 7.2), such a view is simply naïve. There are strong reasons to believe that "the classical concept of probability" is—as are many other concepts—valid only within the "classical domain" (i.e., within the domain the linear dimensions of which are comparable to those of our body). Such a possibility has a powerful impact on the philosophical and theological polemics in this context.

To claim that God uses a noncommutative probabilistic measure in designing the Universe would display an equally enormous naïveté. But the very exis-

44. Boethius, *The Consolation of Philosophy,* 5.6.

45. This does not refer to the term "existence" as it is analyzed, for instance, by Frege, Tarski, Leśniewski, and others. However, their analyses are valid only in the context of a given formal logic, and it is by no means clear which kind of logic one would have to use with regard to the sought-after fundamental theory of physics.

46. See, for instance, P. Teller, *An Interpretative Introduction to Quantum Field Theory,* Princeton: Princeton University Press, 1995.

47. This term has been used by P. Teller (op. cit., 17) as a modern counterpart of the medieval *heacceitas.*

tence of noncommutative dynamical models shows that the idea of an atemporal existence is not contradictory in itself (as has been claimed by many thinkers, especially those belonging to the Whiteheadian school of process philosophy). It would be interesting, then, to look at processes that happen by chance (in the macroworld) from the perspective of the hypothetical Creator who exists "outside" the macrocosmic temporal order and creates the world in an atemporal manner (see subsection 8.1).

> Such a Creator knows the cosmic past, present and future in a single unmediated grasp. God knows the past and the future of each creature, not by memory or by foretelling, then, as another creature might, but in the same direct way that God knows the creature's present. (p. 105)

Our concepts of design or teleology are heavily laden with the all-pervading idea of temporality: pursuing a purpose is a temporal process, and knowledge of its outcome is possible only if the process is strictly deterministic and if its unfolding does not too sensitively depend on the initial conditions. However, the atemporal Creator's knowledge "is not discursive" (p. 106): God does not infer or compute future states of the Universe from knowledge of its previous states. God knows what we call the past and the future by inspection, and consequently in his planning outcomes there is no aspect of expectation. "For God to plan is for the outcome to occur. There is no [time] interval between decision and completion" (p. 106).

The shift of meanings of such interconnected concepts as probability, chance, and purpose has obvious consequences as far as philosophical and theological disputes on the "design argument" are concerned. Let us once more hear what McMullin has to say on this topic:

> It makes no difference, therefore, whether the appearance of *Homo sapiens* is the inevitable result of a steady process of complexification stretching over billions of years, or whether on the contrary it comes about through a series of coincidences that would have made it entirely unpredictable from the (causal) human standpoint. Either way, the outcome is of God's making, and from the Biblical standpoint may appear as part of God's plan. (p. 106)

There still remains the problem of creaturely freedom in such an atemporally created temporal world. Let us notice only that if God does not compute the future but rather sees it from his atemporal perspective, it is immaterial whether the process itself is strictly deterministic or not. For God the outcome is just present.

CONCLUDING STORY

In his commentary on the *Sentences* of Peter Lombard,[48] St. Thomas Aquinas deals with the following problems:

> 1. whether there is only one principle; 2. whether from that principle things come forth by way of creation; 3. whether things are created only by that one principle, or whether they are also created by secondary principles; 4. whether one thing is able to be the cause of another in some way other than by way of creation; 5. whether things have been created from eternity; 6. on the supposition that things have not been created from eternity, in what way God is said to have created the heavens and the earth "in the beginning."[49]

It is interesting to notice that in the first four questions there is no direct mention of time. The temporal aspect of the creation problem appears only in Article 5, "Whether things have been created from eternity," in which St. Thomas presents his famous, and for many surprising,[50] doctrine that the concept of the world existing from eternity but nevertheless created by God is not contradictory. In his view, we know by revelation that the world had a temporal beginning, but this cannot be demonstrated by reason alone. After pondering all arguments for and against the temporal beginning of the world and finding that neither side can convince the other, St. Thomas anticipates the disappointment of his readers and switches to a more rhetorical style (unusual in his writings):

> If someone should argue on the basis of the full-grown man what must be true of the man in an incomplete state in the womb of his mother, he would be deceived. Accordingly, Rabbi Moses, *The Guide of the Perplexed,* tells the story of a certain boy whose mother died in his infancy, who was raised on a solitary island, and who, at the age of reason, asked someone whether and how men were made. When the facts of human generation were explained to him, he objected that such was impossible, because a man could not live without breathing, eating, and expelling wastes, so that it would be impossible for a man to live for even one day in his mother's womb, let alone nine months. Like this boy are those who, from the way that things happen in the world in its complete state, wish to show either the necessity or the impossibility of the beginning of the world.[51]

48. St. Thomas Aquinas, *Scriptum super libros Sententiarum Petri Lombardi,* Book 2, Distinction 1, Question 1.

49. *Aquinas on Creation,* 63.

50. To another of St. Thomas's works on this topic, the posterity gave a telling title: *De aeternitate mundi contra murmurantes (On the Eternity of the World against Those Who Murmur),* see *Aquinas on Creation,* 114–122.

51. *Aquinas on Creation,* 97.

Today we ask such questions as: How old is the Universe? Did it initiate in a "Big Bang"? Will the future theory of quantum gravity remove the initial singularity appearing in the standard cosmological model? Is the fundamental level of the world atemporal and nonlocal? There are many other like queries. All these questions are purely scientific, and we hope that, with the continuous progress in developing our theoretical and empirical tools, we will sooner or later find answers to some of them. I do believe that this will greatly contribute to our better posing of philosophical and theological questions, and more cautiously formulating tentative answers to them. The main lesson we should learn from science in this respect is that we must always be open to broader and broader horizons. St. Thomas drew a similar conclusion from Rabbi Moses' story:

> What now begins to be begins through motion; hence what causes motion must always precede [the motion] in duration and in nature, and there must be contraries; but none of these are necessary in the making of the universe by God.[52]

52. Ibid.