# ENTANGLEMENT AND MATHEMATICS

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### *Introduction: Entanglement and Mathematics*

During the first session of the seminar, Professor Roberto Poli raised the question of the evolutionary origin of reason in a certain context: *The nature of life and the theory of systems*. Reason is a product of life, but life is a product of a systemic universe (built as a dynamic structure). However, in the course of the discussions came the crucial question: How to understand the nature of reason as a product of life and in terms of systems theory? Life arises from a system (the universe) and operates as an adaptive system (as an anticipative system). Therefore, reason might be construed evolutionarily as a representation of systems based on processes of analysis and synthesis of structures.

Poli also affirmed that life (as a whole) is more than a mere combination of the parts, that it is not reducible to physics and chemistry, and that it seems to demand holistic explanations that are today probably still unknown. However, the fact is that, by explaining life in terms of systems theory, it is concerned mainly with elements of sets, analysis, synthesis, systems, structures, relations and operators, cybernetics and self-control, and dynamic evolution of systems / structures, etc. At the same time, attempting to link this perspective with the origin of reason, it was mentioned that reason could be understood in terms of systems analysis: as a natural ability which emerged evolutionarily in life, to form systemic representations of the environment by analysis and synthesis of structures. In this new session of the seminar we will see that reason is not only representation of structures, but intuition of fields of «holistic unity». We must assume therefore that the genesis of reason was not only influenced by the image of reality as a system, but as the feeling of its «holistic unity».

Therefore, Session II of the seminar has brought new facts, ideas and questions that must be re-ordered in the context of the theme of the seminar (the evolutionary origin of reason).

Professor Gregor Nickel raised doubts as to any «naturalistic» explanation of reason, on the claim that natural sciences are written in the language of mathematics and the consequent mathematical dependence of physics. Nickel argued in favour of releasing mathematics of «naturalism», conceiving mathematics as a free creation of reason and viewing mathematics as an extreme example of autonomous self reflection on its own based on that freedom.

Professor Harald Walach, on the other hand, described a «generalized model of complementarity» to explain reality. He described the physical principle of complementarity in quantum mechanics and argued that this concept could be generalized to understand consciousness and other phenomena in which consciousness connects with the physical world. He also pointed out that a generalized quantum non-locality (entanglement) could be of importance even for macroscopic objects. Complementarity could be the key to understanding holistically correlated behaviour on different levels of systemic complexity.

Regarding the theme of the seminar – the evolutionary origin of reason – the ideas introduced by Nickel and Walach generate great interest that substantially broaden the outlook opened after the session with Poli on evolution of life and anticipation (and theory of life systems). We can outline some of the issues and questions arising from the presentations of Nickel and Walach.

In connection with Nickel's reservations about the viability of a «naturalistic» explanation of mathematical reason, there is a fundamental perplexity. If reason has not emerged evolutionarily, where does it come from? Does it make sense to think that mathematical reason is not part of nature? Today there seems to be no reasonable alternative to the general evolutionary paradigm of science. If a certain way to describe the nature of evolution (e.g., reductionism) is not compatible with the phenomenological experience of mathematical reasoning, then should we not abandon the naturalistic explanation? A better way might be by seeking an alternative new description of nature (that is non reductionist).

The contribution of Walach has shown how the human being is open to a dual, but complementary, experience of reality. Not only physical reality in physics is experienced as complementary (the wave-corpuscle irreducibility). The general principle of complementarity means that the psychological experience of reality is open also to a dual experience: a deterministic physical world of individual differentiated particles and a holistic world that Walach describes as a generalized experience of entanglement (PDR effects). Applying the principle that not only humans but also life in its evolutionary process (at different levels of sensitivity-consciousness) has this dual/complementary experience of reality, we could thus be led to believe that reason has been produced by this dual experience. In other words: the evolutionary causes of reason would not only be the experience of a differentiated/deterministic world (classical), but also the experience of a holistic world by entanglement (quantum).

Therefore, the horizon opened by Walach introduces some insights to Poli's proposal. Could it be that reason emerges as a result of the experience of a systemic world? If so, reason works through analysis and synthesis of structures. But human beings and the superior human reason have not only experience of a differentiated/deterministic world (classical systems), but also of a holistic world that we do not know whether it can be described in terms of classical systems or not. However, this experience has played a decisive role in the emergence and the evolutionary nature of reason. What is the influence of that experience of holism and entanglement in the constitutional process of human reason? This is an open question.

For Nickel, the self-experience of mathematical reason (and its own model of reflection about itself) encourages reason against any form of naturalism (and naive monism). Mathematical reason expresses creative freedom, independent of physical objective reality. Mathematics is a world created by the human mind that is not subject to a deterministic physical world. Nickel's presentation also contains a complementary experience: the world of deterministic physics and the world of mathematical creation. Nevertheless, if according to Walach's approach, reality is also in its very natural constitution (in the physical and in the psychological, let us say in the mind) «complementary», could it not be that mathematical reason was based at the same time on classical experience and on holistic experience of reality? If so, mathematical reason could have in part a natural origin in the holistic ontology of reality (not only in the physical world in a «reductionist» sense). Mathematical reason (the mind) and the creative freedom versus a robotic world, could well be explained in a «naturalistic» but «non reductionistic» way (that science seems to require).

## I. NIKELS FRAMEWORK PAPER: REASON'S NATURE, THE ROLE OF MATHEMATICS

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### 1. PRELUDE

Let us start with a little story playing in St. Petersburg in the 18th century. Leonhard Euler (1707-1783), one of the greatest mathematicians of all times, met Denis Diderot (1713-1784), a leading man of the French enlightment and a charming defender of Atheism. Euler was introduced to Diderot as a person who found an algebraic proof for the existence of God. Showing a poker face, Euler said: «Monsieur, we have

$$a + b^n/n = x,$$

thus God exists: your turn!» Diderot was totally baffled and did not manage to reply. Everybody laughed at him, and soon afterwards he returned to France.

Indeed, within a theological or philosophical debate you can easily intimidate your opponent by a mathematical argument. Thereby mathematics takes profit from a property which could almost be described as a coincidence of opposites: Namely, on the one hand a mathematical formula, calculation or argument is usually incomprehensible for the opponent. On the other hand, however, it

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promises a complete transparency – at least in principle. Thus the miserable opponent – searching for insight – struggles mainly with his own ignorance. So he will not be able to contradict the argument – let alone to question whether it is legitimate to use mathematics at all. Of course, then the mathematician has an easy game to play.

Please don't panic; this paper will not terrorize the reader with any mathematical formalism. Far from it! Mathematics will not be a tool for any argumentation, but rather the object under consideration.

### 1.1. *Reason's Nature – Twofold Understanding*

It is not by chance that the expression 'Reason's Nature' in the in the title can be interpreted in a twofold way.

First, we have 'nature' as the object of inquiry seen by (human) reason; here reason denotes the type of question we pose, namely that we are interested in describing our object in a 'reasonable' way. In particular we may think about nature within the framework of natural science – a framework developed by Galilei, Newton and their successors which today claims to be the canonical frame of reference for any question about nature.

Second, however, we might speculate about the 'natur of reason', i.e., try to describe reason itself. Now nature denotes the type of question we pose, namely that we look for the essence of reason, not just some arbitrary features of it. For this second question, it is not so easy to find a canonical frame of reference. We may just mention the long lasting tradition of philosophical reflection about the human mind or the various attempts of a mental introspection (philosophical, theological, religious, mystical, etc.), but also approaches to characterise human reason by the works of human culture: arts, religion, sciences, etc.

Apparently it is tempting to draw back to our first reference frame. Our 'best' descriptions of nature are presented by natural science – at least this is often claimed to be so. Thus, why not analyzing reason's nature within this scientific framework? It is thus nowadays all too common to identify the above sketched two different endeavours; the result is a picture, where reason has emerged during the course of an evolutionary process and now it can be found within human brains. We thus try to describe reason as a phenomenon within time and space – whatever time and space might be.

Anyway, we find various approaches within this scientific perspective, e.g., evolutionary biology and socio-biology, neurophysiology, etc. If these go beyond the investigation of special phenomena and try to present an encompassing and consistent theory of human reason we may call this a naturalistic approach.

In my paper I will first observe what happens if the two perspectives are identified in the above naturalistic way. Second, I will follow the first understanding separately, thus ask for the scientific perspective on nature and the role of mathematics for it. Third, I will follow the second understanding and try to observe mathematics as a quite special ability of human reason. Finally, I will again examine possible relations between these two.

## 2. Ridiculous Circles

### 2.1. *Naturalism*

If we try to take naturalism at its words we might end up with the following or a similar argumentation. Human reason, within human brains, is nothing but an electrical process within a network of brain cells. These brain cells and electricity consist in the movement of elementary particles (or is the evolution of an elementary field, if you prefer this picture). But what is an elementary particle? It is just a mathematical structure (to be more precise, an irreducible (unitary) representation of the chosen symmetry group of space-time). But how do we now, what a mathematical structure is? If we refuse to be Platonists – which the naturalist should do – we will interpret mathematics as consisting of symbols or marks written down on the blackboard with chalk. Now the question is: What is chalk? And I will go on in the argumentation by quoting the great mathematician Herman Weyl (1885-1955) who stated it 1948 as follows:

> «As a scientist we may be tempted to argue like that: 'As we know, chalk consists of molecules and these in turn are built from (...) elementary particles (...) However, analysing what theoretical physics means by these words, we saw, that these physical objects are dissolved into a mathematical symbolism; the symbols, however, are finally concrete marks written with chalk on a black board. You certainly will notice the ridiculous circle» [2].

I think, any attempt to interpret the scientific results with the aim of a consequently naturalistic position – if it does not invisibilise its consequences – will run into a similar 'ridiculous circle'.

### 2.2. *Projections in Science-Religion*

The status, however, of many arguments in the so called 'Science-Religion-Dialogue' is not muchbetter. They also start with a 'maximal interpretation' of science – thereby often projecting the author's preferences or spiritual needs onto the scientific 'facts'. Following this way, lowbrow metaphors such as the 'big bang' or purely technical terms such as 'chaos' gain an unjustified and mostly unclear metaphysical meaning. Remark here, that the interpretation of these scientific 'facts' is often quite arbitrary [3] – the very same astronomy, e.g., can lead to an identification of the universe with a «co-creative cosmos» or a «senseless one» (as Jacques Monod coined it).

In the end we might obtain the sort of arguments Alan Sokal [4] was scoffing at. Under the title: *Transgressing the Boundaries: Towards a Transformative*

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[2] See Weyl, H., «Wisssenschaft als symbolische Konstruktion des Menschen». In: *Gesammelte Abhandlungen.* Bd. IV, Springer, Berlin, 1968, p. 342.

[3] For more details see [Ni99a].

[4] See Sokal, A., *Transgressing the Boundaries: Towards a Transformative Hermeneutics of Quantum Gravity.* SocialText 46/47, 217-252.

*Hermeneutics of Quantum Gravity* he presented a completely nonsensical paper to the renowned Journal Social Text. By quoting the 'important people' using some stylish political catchwords and mixing this up with an incomprehensible fluff of technical slang from theoretical physics he could bluff the editors, his nonsense passed the referee process and it was published. In fact a naive transgressing disciplinary boundaries calls for this type of mocking. Just to mention the classical example: Recall Voltaire's *Candide* showing that Leibniz' application of the (mathematical) principle of least action to ethical questions leads to an irremediable confusion.

In our times, we have to face an even more serious situation. Science became an extremely filigree network of specialised disciplines with their very own results and standards of argumentation. Not even the most important results within mathematics could be overseen by one person as it was possible for a Hilbert in 1900; let alone the results of natural sciences.

At the same time science has given up its competence for presenting a 'world view'. Every specialist has just a very small range of (practical or theoretical) knowledge, but sometimes an even stronger desire for an all-embracing orientation. Since it seems to be out of style to simply follow the doctrines of a church or a philosophical tradition these people apparently are tempted to tinker their personal 'philosophy' based on the 'results' of science they (pretend to) understand.

It is thus misleading to cross disciplinary boundaries without being aware of changes in language and meaning and without control of the effects. Any uncritical interpretation of the results of natural science is a quite problematic endeavour. The question on the epistemologic basis is indispensable.

### 2.3. *Methods instead of Results*

To me it seems to be more reasonable to analyse the *instruments* of human reason for doing science instead of using these instruments to analyse reason. The focus then lies on the scientific method, and in particular on *mathematics* and experiment. Remark that now the subject is quite constant in contrast to the transient and difficult to understand scientific results.

## 3. Reason's Nature – Nature mathematically described

It is an indisputable fact that modern science heavily relies on mathematics. Just recall Immanuel Kant's (1724-1804) famous claim that in every *special natural doctrine only so much science is to be met with as mathematics* [5]. Indeed, today's scientific theories are codified by a mathematical formalism together with a minimal interpretation (which is usually operationalistic) for the theoretical terms linking these to appropriate elementary experiments. The method of science can thus be characterised by three moments: A mathematically codified theory.

[5] See Kant, I., *Metaphysische Anfangsgründe der Naturwissenschaft*. A IX.

Experimental praxis, and a minimal interpretation connecting theory and experiment. In general this is sufficient for the internal discourse of natural sciences and its technical *applications*.

If we ask for the relation between the rigor of mathematical formalism and the ambiguity of the real world we might answer as Albert Einstein (1879-1955) put it:

> «As far as the propositions of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality» [6].

In spite of Albert Einstein's well-known ironical warning since the days of Galileo Galilei natural science uses mathematics as if it were the language of nature. Of course, Einstein's theory and philosophical attitude, is a paradigmatic example for this.

### 3.1. *Mathematics as the language of natural science*

The metaphor of mathematics being the language of nature is at least as old as modern science itself; it may be sufficient to recall Galileo Galilei's (1564-1642) famous quote from the Il saggiatore (The Assayer) where he states:

> «Philosophy [nature] is written in that great book which ever is always before our eyes – I mean the universe – but we cannot understand it if we do not first learn the language and grasp the characters in which it is written. It is written in the language of mathematics, and the characters are triangles, circles and other geometrical figures, without whose help it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth».

This claim mightbe tough stuff for all non-mathematicians – who probably did not have the impression to be stumbling helplessly through a dark labyrinth [7].

It is, however, not nature itself, but the books of natural science which prove Galileo's statement true. In fact, the universal language of thesebooks is mathematics. Though the Phythagorean creed – Galileo empasised so brilliantly – may be the conviction of many scientists, the equation 'mathematics=language of nature' has been questioned from both sides. On the one hand, philosophers emphasise that mathematics could only grasp some aspects of nature, that the whole reality of the world is much richer than any mathematical structure could grasp – and this holds already for Aristotle. On the other hand, in the 20th century mathematics became more and more independent from its linkage to the sciences. Only the character of language remainded from Galileo's metaphor, but it is not obligatory that mathematics has to talk about nature. If you adopt a strictly formalistic view, mathematics is not obliged to talk about any object – it is then a language without any meaning. However, by giving up any semantical

[6] See EINSTEIN, A., «Geometrie und Erfahrung». In: Ders.: *MeinWeltbild.* Ullstein, Berlin, 1988, S. 120.

[7] See GALILEI, G., *Il saggiatore,* p. 25.

commitments mathematics gained an enormous flexibility to define and examine various structures. As a result, out of this stock the demand of the scientists could be satisfied even easier.

It could thus seem as if mathematics were just a neutral language; only the content is relevant not the form. However, to use mathematics as the language of science has many material implications which should be analysed also critically. Without any claim of completeness I will now sketch some special features of the mathematical language. How far this language is suitable for a special situation must be decided case by case.

1. Mathematics is unique as a language by its extremely broad and at the same time extremely clear cut criterion for the ongoing or ending of the communication, respectively. Any 'false' proposition or (steps of) argument or calculation must be ruled out, however, only these. Mathematics can talk about any object, whose structure could grasped by true or false propositions. The German philosopher and sociologist Niklas Luhmann (1927-1998) characterised mathematics by a peculiar combination of indetermination with respect to content and determination with respect to form – similar to money only[8]. One effect of this is that usually discussions among mathematicians about the validity of an argument are comparably short.
2. To obtain this rigor, mathematics has to rule out any vagueness of its symbols (as far as this is possible). Strict identity of the marks is assured by definition – every x will remain just the same x throughout a mathematical paper without any dependence of the context. The translation of a mathematical text is nothing else than a mere change of notation and thus possible without any loss. This is in contrast to all other natural languages, where translation means always interpretation[9]. With mathematics the situation is much easier, the language is clear as crystal, but at the same time we lose the ability of languages to express ambiguities or less sharp passages in meaning, we loose, e.g., humor, irony, esprit, tact.
3. Moreover, the mathematical discourse has a double face of despoty and subversion. The despotical aspect is nicely illustrated in the following cartoon.

   Contrary to this classroom situation, there is no democracy in mathematics[10]. On the other hand, the social position of the dialogue

[8] See LUHMANN, N., *Die Wissenschaft der Gesellschaft*. Suhrkamp, Frankfurt, 2009, p. 200.

[9] The e.ect of (bad) translations is quite dramatical ifyou compare sophisticated argumentations in your mother language with that kind of piggin, international science nowadays uses.

[10] The winning of dialogues is consequently the intuitive background for a constructive approach to formal logic by Paul Lorenzen and Oswald Schwemmer. Aclaim is provable, if you have a definite strategy for winning such a dialogue; see LORENZEN, P. - SCHWEMMER, O., *Konstruktive Logik, Ethik und Wissenschaftstheorie*. BI, Mannheim, 1973. It is however, still an open question, how we see that such a strategy will necessarily lead to the goal.

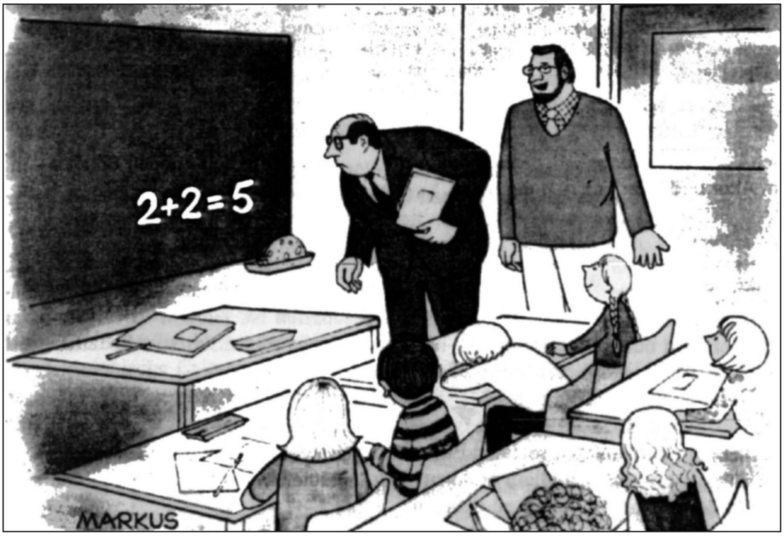


FIGURE 1: *Sorry, principal, but we made a poll about the result.*

partners is completely irrelevant; to defend a mathematical theorem you cannot invoke authorities, only a coherent proof counts, the discours is 'herrschaftsfrei' (free of domination) in an ideal sense; thus there is also a subversive aspect.

Once such a (formal) proof is given every opposing view is without any chance. You cannot argue in favour of a mathematically disproved theorem without leaving the club of reasonable people. Then the proof exhibits its despotical aspect.

4. The impact on an object mathematical language has can be observed especially acurate when we look at the mathematisation of language itself, e.g., if we observe formalised or mathematical logic. Let me quote David Hilbert (1862-1943), the leading mathematician of the 20th century, who claims

> «that the usage of language is the essential characteristics, by which human beings separate from all other creatures» [11].

His reduction of language to its 'essence', however, reduces its function to mere unique denotation:

> «If we survey the languages familiar to us, we observe a great similarity in structure. The di.erences are basically just the conventions to use di.erent

[11] «[…] dass dasjenige Hilfsmittel, durch das sich der Mensch uber die anderen Lebewesen ërhebt, im wesentlichen die Sprache ist». For this and the following quotes see HILBERT, D., *Wissen und mathematisches Denken*. Vorlesung ausgearbeitet von Wilhelm Ackermann. Göttingen, 1988, p. 92.

> words, di.erent names (...) It is completely irrelevant if you say 'table', 'mensa' or 'Tisch' and tree, Baum, arbre or dendron» [12].

The result of his research for the basic structure of language [13] is formal logic, thus the

> «articulation of thoughtsbecomes essentially the operating with notions» [14].

It is a special irony if he characterises the goal of formal logic by a mechanization of human reasoning. Paul Isaac Bernays (1888-1977) one of Hilberts most prominent pupils states it as follows:

> «After having found the principles of logical reasoning, nothing else has to be thought. The rules of reasoning must eliminate thelogical *thinking*. Or else we would need other rules, how the first rules must be applied. This requirement of an expulsion of spirit could in fact be fulfilled» [15].

Probably essential aspects of natural language *and* of human reason were eliminated thereby. This is pinpointed by an ironical remark of Kant's contemporary Johann Georg Hamann (1730-1788). He criticised the monarchy of mathematics, the strange forcing character of its proofs, becomingthe ideal of any reasoning. Should the uniqueness and inevitability of the results be the essential advantage, then human reason would have found a much better working equivalent in the instinct of an insect.

> «Endlich versteht es sich am Rande, daß, wenn die Mathematiksich einen Vorzug des Adels wegen ihrer allgemeinen und nothwendigen Zuverläßigkeit anmaaßen kann, auch die menschliche Vernunft selbst dem unfehlbaren u[nd] untrüglichen Instinct der Insecten nachstehen müßte» [16].

### 3.2. *Why mathematics for the sciences?*

But why does mathematics play this indispensable role for natural sciences? Again we could quote Kant:

> «They [all students of nature] learned that reason has insight only into that which it produces after a plan of its own (...). Reason, holding in one

[12] «Wenn wir die Sprachen, die uns nahe stehen, Ahnlichkeit uberblicken, so dringt sich die in der Struktur auf. Die Unterschiede sindwesentlich nur die Konvention, dass andere Worte, andere Namen gebraucht werden. [...] Ob man table, mensa oder Tisch, [...] ob man tree, Baum, arbre oder dendron sagt, ist ja ganz unwesentlichund gleichgültig».

[13] «Auf die Struktur der Sprache gerichteten Untersuchung».

[14] «Das Aussprechen der Gedanken wird wesentlich zu einem Operieren mit Begriffen».

[15] «[N]achdem einmal die Prinzipien des Schließens genannt sind, [braucht nun] nichts mehrüberlegt zu werden. Die Regeln des Schließens müssen so beschaffen sein, dass sie das logische *Denken* elimieren. Andernfalls müßten wir ja erst wieder logische Regeln dafur haben, wie jeneRegeln anzuwenden sind. Dieser Forderung der Austreibung des Geistes kann nun wirklichgenügt werden». See BERNAYS, P., *Abhandlungen zur Philosophie der Mathematik*. Wiss. Buchgesellschaft, Darmstadt, 1976, p. 9.

[16] See BAYER, O., *Hamanns Metakritik Kants*. Frommann-holzboog, Stuttgart, 2002, p. 296.

> hand its principles, according to which alone concordant appearances can be admitted as equivalent to laws, and in the other hand the experiment which it has devised in conformity with these principles, must approach nature in order to be taught by it. It must not, however, do so in the character of a pupil who listens to everything that the teacher chooses to say, but of an appointed judge who compels the witnesses to answer questions which he has himself formulated. Even physics, therefore, owes the beneficent revolution in its point of view entirely to the happy thought, that while reason must seek in nature, not fictitiously ascribe to it, whatever as not being knowable through reason's own resources has to be learnt, if learnt at all, only from nature, it must adopt as its guide, in so seeking, that which it has itself put into nature» [17].

The mentioned principles of reason are given by mathematics; Kant's argument for this, briefly, is the following: Any empirical science needs a theoretical framework first. This theory must be *a priori*, thus it cannot be based on the reality but mere possibility of objects, since reality could only be analysed by experience. The possible objects of the natural sciences, however, must be given in time and space – it is not sufficient, that the respective concepts are free of contradictions. Thus the theoretical concepts are to be based on *a priori* constructions in time and space – this, however, characterises the working of mathematics [18]. We will not go into a detailed discussion of this claim – especially the synthetic character of mathematics, which is so important for Kant's point of view is still quite controversial – but instead focus on the active role, the scientific observer plays in his concept. Another quote may emphasise this point:

> «[T]he order and regularity in the appearances, which we entitle nature, we ourselves introduce. We could never find them in appearances, had we not ourselves, or the nature of our mind, originally set them there» [19].

Again, this thesis exhibits an ambiguous use of the word *nature* which is indicative of a central problem. On the one hand, there is the unity of the (human) subject, whose orderly internal «nature» is capable of developing mathematics. The use of this instrument in turn guarantees (a description and the manipulation of) the orderliness of the external «nature». Any all-too easy identification of these two natures leads – as we have seen – to a naive monism of various types – be it materialistic or idealistic.

## 4. Reason's Nature – Reason creating mathematics

In this second part, we will invert the direction of the title question. How to characterise the natur of reason? I will not even try to sketch a picture of the

[17] KrV, B XIII.

[18] Compare the argumentation in Kant, I., *Metaphysische Anfangsgrunde der Naturwissenschaft*. A IX

[19] KrV, A123.

various abilities of human mind; already reason – as a special facet – has a tremendous variety of aspects. I will just consider *one* quite special and quite strange ability, namely our ability to produce mathematics. Following Kant's traces – we will thus focus on mathematics bridging between the human intellectual constructions and the empirical data. From an epistemological point of view we will ask for the 'nature' of mathematical structures.

### 4.1. *Mathematics and Freedom*

In the Platonic description, mathematical objects or structures are somewhat 'outside' the mathematician, eternal entities to be studied or contemplated. It is then a quite special ability of the human mind's eye to 'see' these eternal forms. And remark that Platon profitted in his argumentation decisively from this fact. Just recall the arguments in *Phaidon* and *Menon* against any sceptical or naturalistic doctrine and finally leading to the central metaphors of the *anamnesis* and dialectics as the *second best navigation*.

The first major break, however, with this purely theoretical character of mathematics is due to a theologian, Nikolaus Cusanus (1401-1464). According to Nikolaus the human mind is the creator of the objects of mathematics – parallel to God's creation of the world:

> «The human mind, which is an image of the Absolute Mind and which in a human fashion is free, posits, in its own concepts, delimitations for all things; for it is a mind that conceptually measures all things. In this conceptual way it imposes a delimitation on lines, which it makes to be long or short; and it imposes end-points on the lines, just as it chooses to. And the human mind first determines within itself whatever it proposes to do; and it is the delimitation of all its own works» [20].

This prominent theological topos, namely the free *creatio ex nihilo* of the multitude of things out of and due to the (trinitatrian) unity of the Creator can indeed uniquely be understood using the model of mathematics [21]: The unity of the human mind generates the diversity of mathematical structures like God is creating the real beings:

> «[T]here is a single infinite equality-of-being unto which I look when I draw different figures. Therefore, [by comparison], when the Creator creates all things, He creates all of them while He is turned toward Himself, because He is that Infinity which is Equality-of-being. It is the One infinite equality of being, on which I look, if I draw the various mathematical figures. Turning to

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[20] See *De venatione sapientiae* c. 27 (h XII n. 82, 13-17): «Mens enim humana, quae est imagomentis absolutae, humaniter libera omnibus rebus in suo conceptu terminos ponit, quia mens mensurans notionaliter cuncta. Sic ponit terminum lineis, quas facit longas vel breves, et tot ponit punctales terminos in ipsis, sicut vult».

[21] We are thus confronted with the question how Gods unity expresses herself in the multitude of the world. The figure of Nikolaus for this is *complicatio*, enfolding, and *explicatio*, unfolding. And it can just be illustrated by the rational action of the mind doing mathematics.

> Himself the creator creates everything, since he is the infinity which is the equality of being» [22].

Moreover, the mathematical knowledge is more rigid than any other, precisely because the mathematical structures are our own constructions [23].

Going one step further, we see that mathematical structures neither drop from heaven nor can they directly be found in nature. As the history shows, mathematical concepts are not invented as completed and unchangable objects, but are shaped and improved during the centuries. Probably Husserl's concept of *Limesgestalten* is more adequate than the never-never land's ideas of platonism.

For me the important point is, that mathematics is intimately connected with a special aspect of human freedom; the freedom to define and choose consitant rules and to freely obey these. During the course of the early 20th century we can observe a major change with respect to this question. It is wellknown that the result is a switch from external to almost purely internal reference leading to a far reaching autonomy of mathematics. It lies in the *free* choice of the mathematician, which special set of axioms he likes to start with [24]. No external object dictates a certain set. And it is hardly exaggerated when Georg Cantor (1845-1918) claims:

> «The essence of mathematics is freedom» [25].

However, this freedom is restricted in a twofold way we discussed already above. First, there is no freedom of interpretation and no context dependence of the terms. There is – so to speak – no hermeneutical problem in a mathematical text. This strong concept of identity enables and leads to the second restriction: the chosen axioms are not allowed to contain contradictions neither explicitely nor implicitely. The anxious emphasis on this consistency, is the prize we pay for the freedom of choice with respect to the axioms. Thus mathematics could be characterised as being the free enfolding of human mind strictly respecting the self-limitation of identity and consistency.

## 5. Circles of Reflection

Coming to the last part of my talk I have to admit, that I apparently commited the same crime I accused the naturalist: I repeatedly used the expression

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[22] See *De Complementis Theologicis* [Cu, p. 668]: «Una igitur infinita essendi aequalitas est ad quam respicio, quando diversas depingo figuras. Creator igitur dum omnia dreat ad se ipsum conversus omnia creat, quia ipse est infinitas illa, quae est essendi aequalitas».

[23] For a more profound analysis of Cuanus we refer to [Ni04], [Ni05a], [Ni05b], [Ni05c].

[24] Herbert Mehrtens discusses the development of modern mathematics and the disputes during the so called foundational crisis under this aspect of creative freedom, see Mehrtens, H., *Moderne Sprache Mathematik*. Suhrkamp, Frankfurt, 1990. Here David Hilbert – following Georg Cantor – stands for a progressive modernity against Luitzen Egbertus Jan Brouwer (1881-1966) – following Leopold Kronecker (1823-1891) – being the representative of reactionary anti-modernity which claims a necessary external reference for mathematics.

[25] «Das Wesen der Mathematik liegt in ihrer Freiheit» (translation by the author), quoted from Purkert, W. - Ilgauds, H. J., *Georg Cantor*. Birkhäuser, Basel, 1987.

'reasonable' and I tried to give you arguments to be followed by reason – but the very question remained unsolved, what this myterious *reason* actually might be.

In fact, we find a remarkable insight in these ridiculous circle already in the Greek philosophy; Platon pinpoints it almost at the end of his Theaitetos – where a similar question for the essence of knowledge is discussed:

> «But really, Theaetetus, our talk has been badly tainted with unclearness all along; for we have said over and over gain "we know" and "we do not know" and "we have knowledge" and "we have no knowledge", as if we could understand each other, while we were still ignorant of knowledge; and at this very moment, if you please, we have again used the terms "be ignorant" and "understand", as though we had any right to use them if we are deprived of knowledge» [26].

As it seems to be impossible to strictly avoid this sort of circulariry – or else to quit talking at all – in my concluding section I will now focus on this phenomenon.

It is often claimed that mathematics takes a special third position between the natural sciences and the humanities. I will now characterise this position with respect to the built in reflection. Thus, the criterion is the ability of a science to reflect about its own foundations by its own methods.

Natural sciences are ruling out such reflections on the foundations systematically. Of course, there *are* intensive discussions about the basic concepts of theory and experimentation especially before paradigm changes – see the change in time and space concepts due to special relativity or the change in the state concept due to quantum mechanics. However, even these revolutions remainded within the framework of mathematical theory and experimental praxis. Science itself remains completely outside its objects, the observer in physics is not its own problem. If these circles are thematised explicitely we run into paradoxes. The question of the essence of physics is not a physical question, that is, it will not be tackled by physical methods. In fact, it would be unfair to require an experiment by which we could answer the question, whether the experimental method is valid at all. Georg Picht (1913-1982), a German philosopher, expressed this position very clearly:

> «Natural scientists can do there research only, because since Galilei they decided to ignore the immensely difficult question what it is that enables their knowledge. They do not ask for nature in itself, since the became aware, that the renouncement to posing this question opens a wide playing ground for the naive research on phenomena within nature» [27].

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26 PLATON, *Theaitetos* 196e.

27 «Die Naturwissenschaftler können ihre Forschungen nur deshalb betreiben, weil sie seit Galilei beschlossen haben, die unermeßlich schwierige Frage, was sie zu ihren Erkenntnissen befähigt, auszuklammern. Sie fragen nicht nach der Natur überhaupt, weil sie entdeckt haben, daß der Verzicht, diese Frage zu stellen, ihnen Spielraum gibt, sich unbefangen der Erforschung der Phänomene *innerhalb* der Natur zu widmen». See PICHT, G., *Der Begriff der Natur und seine Geschichte*. Klett-Cotta, Stuttgart, 1990, p. 4.

In constrast to this, reflection is an integral feature of all humanities, and especially for philosophy. Philosophy and its method is a problem and an object for philosophy which must never be forgotten.

Concerning mathematics, we observe a strange phenomenon: The very foundations of mathematics could be discussed by mathematical methods, it could be formulated as a mathematical problem and – almost (!) – be solved. Of course, the most intensive phase of this endeavor was the foundational debate (or crisis) of the 20th century's first half. Here, the primarily philosophical question for the laws of reasoning, the acceptable methods of proof and the certitude of mathematical theorems could be translated into mathematical or 'meta-mathematical' questions; the concerned mathematical subdisciplines were: Mathematical logic, Proof theory, set and model theory. To briefly characterise this approach, the *process* of a mathematical proof could be translated into a formal series of signs and thus into a mathematical *object*. So one could formalise provability and show mathematical theorems *about* this mathematical reasoning. Finally, these foundational work became just another mathematical subdiscipline and the working mathematician could continue to do his job unburdened. Certainly, the results of Kurt Gödel showed heavy restrictions to this foundational approach, however, by mathematical means!

Thus, mathematics did not completely ignore the 'immensely difficult question what it is that enables its knowledge', but it could mitigate it in a way such that it will not bother the ongoing of the research. There is no formal, thus no strict proof for the soundness of the (or any sufficiently powerful) axiomatic ground of mathematics, just intuitive arguments. However, these are sufficient to go on with the work without any further counterinsurance. If there appears any contradiction within a branch of mathematics it will be ruled out radically; but it serves also as a wellcome impulse to meliorate the foundations. Examples for this are the deepening of the concept of a function – from Leibniz to Cauchy and Weierstraß – and the developement of set theory after Bolzano and Cantor.

In the last consequence mathematics can only be analysed by mathematical methods if one accepts contradictions, and that means not at all. However, this at least can be shown by mathematical reasoning. Let me finally quote Bernays again:

> «A philosophical interpretation of the antinomies of axiomatic set theory is that mathematics as a whole is not a mathematical object. Thus, mathematics can only be understood as being an open plurality» [28].

I hope I could show that it is worth the trouble to examine this open plurality – called mathematics – more closely,

[28] «Philosophisch kann das Verfahren der Lösung der Antinomien durch die axiomatische Mengenlehre in dem Sinne gedeutet werden, […] dass man die Antinomien als Anzeichen dafür nimmt, dass die Mathematik als Ganzes nicht ein mathematisches Objekt bildet und dass also die Mathematik nur als eine offene Mannigfaltigkeit verstanden werden kann». See BERNAYS, P., *Abhandlungen,* p. 174.

1. since it encourages reason against any form of naturalism (and naive monism),
2. since it shows a strange form of relatedness of human reason to freedom,
3. and, finally, since it gives a model for the strange phenomenon of reflection.

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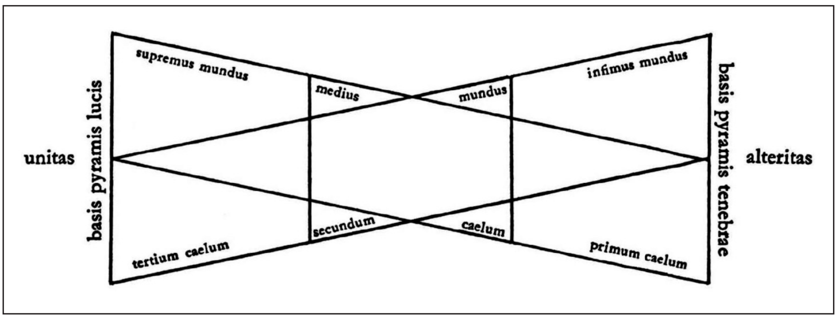

## II. SESSION PROCEEDINGS OF NIKELS PRESENTATION

### Presentation: Twofold Understanding

The title *Reason's Nature* can be interpreted in two ways: in one of them *nature* is the object that we try to describe in a *reasonable* way (usually, but not inevitably within the framework established by natural sciences); in the other way, we might speculate about the *nature of reason*, trying to describe the essence of *reason* itself (for this quest there is no canonical framework, but diverse approaches based on mental introspection, as done by philosophy, theology, religions, mysticism, etc., or departing from human cultural works, as those of the arts or sciences). One option is to analyze reason's nature within the scientific framework, thus identifying the two different tasks, so that *reason* is understood as emerged during the evolutionary process, as a phenomenon within time and space (whatever they might be). When the sciences go beyond the investigation of these special phenomena and try to present a consistent theory of human reason we may call this a naturalistic approach. During his talk, Prof. Nickel first examined the case when the two perspectives are identified and then followed them separately, paying special attention to the role of mathematics in the scientific perspective on nature (second part) and observing this discipline as a special ability of human reason (third part). Finally, he presented possible relations between these two perspectives.

### 1. Naturalism: Ridiculous circles

From a naturalistic approach, human reason is nothing but an electrical process within a network of brain cells, consisting in the movement of elementary particles (or, e.g., the evolution of an elementary field). The concept of elementary particles corresponds however to a mathematical structure, so that if the naturalistic position is held consequently, the whole explanation dissolves in mathematics. This circle becomes even more ridiculous if a purely formalistic concept of mathematics is presupposed; the symbols of math then are just meaningless marks of chalk at some blackboard.

In the science-religion dialogue the scientific results are usually interpreted in a philosophical way, often assigning to technical terms an unclear metaphysical meaning. But science is such a complicated network of specialized disciplines that it has given up its competence for presenting a 'worldview'. To cross disciplinary boundaries uncritically could be misleading and very problematic. It is indispensable to take into account the necessary epistemological bases.

Nickel defends that it is more reasonable to analyse the *instruments* of human reason for doing science instead of using these instruments to analyse reason.

## 2. Reason's Nature: Nature mathematically described

Modern science relies heavily on mathematics. We could even say that mathematics is the universal language of the books of natural science. But the equation 'mathematics=language of nature' has been questioned from both sides: philosophers say mathematics can only grasp some aspects of nature and mathematicians have recently become more and more independent from science.

Mathematics can be used as a language, but its use in science has many implications. Some special features of the mathematical language are:

- It is a language extremely broad and extremely clear. Anything can be talked about with it, as long as its structure can be grasped as a set of propositions. Then its criterion for ruling out the false propositions is very clear cut.
- The mathematical rigor requires a strict definition of its symbols, ruling out any vagueness, and with it the ability to express ambiguities, and subtleties as humour, irony, tact, etc.
- The mathematical discourse has a double face of despotism (the correct results are not established by a democratic vote) and subversion (only a correct proof counts, not the social status or otherwise authority of its defender).
- A mathematization of natural language does sometimes also occur, language's function is reduced to mere denotation and any thinking or reflection idealized to a mechanical formal reasoning, so that essential aspects of human reason or communication get eliminated.

Mathematics is an appropriate tool for natural sciences because it gives them the *a priori* constructions that they need for their theoretical frameworks. The problem is that with the *a priori* construction the orderliness of the internal 'nature' of the human subject (capable of developing mathematics) is extrapolated to the external 'nature', as perceived by the sciences, or, ultimately, by human reason. Any all-too easy identification of these two natures leads to a naive monism of various types either materialistic or idealistic.

## 3. Reason's Nature – Reason creating mathematics

Prof. Nickel restricted this part of his talk to only one quite special aspect of reason, our ability to produce mathematics. The 'nature' of mathematical structures will be examined, and their function as a bridge between the human intellectual constructions and the empirical data.

Plato described the mathematical objects or structures as eternal entities existing 'outside' the mathematician. The first to break with that tradition was Nikolaus Cusanus, when he proposed that the human mind is the creator of the mathematical objects, parallel to God's creation of the world. However we learn from history that mathematical concepts are not invented as completed and unchangeable objects, but are shaped and improved during centuries. The important point for Prof. Nickel is that mathematics is intimately connected with a special aspect of human freedom, the freedom to define and choose consistent rules and to freely obey them. The mathematicians of the 20th and 21st centuries choose freely the set of axioms they liked to start with. This freedom is, nevertheless, restricted in two ways, the self-limitation of identity and consistency: A strong concept of identity, meaning that there is no freedom of interpretation and no context dependence of the utilized terms, and that the chosen axioms are not allowed to contain contradictions neither explicitly nor implicitly.

## Conclusion – Circles of Reflection

Nickel admitted in this moment to have incurred himself in a ridiculous circle in his talk when speaking of 'reasonable' arguments without explaining what this mysterious 'reason' actually is. It's a sort of circularity seemingly impossible to avoid (cf. Platon's *Theaitetus*).

Natural sciences usually do not and cannot reflect on their own foundations, the sciences and the scientists remain completely outside of their fields, since they never observe themselves as their own objects. They assume that their method is valid, although this cannot be proved within their own disciplines and go on with their theories and experiments. In contrast to this, reflection is an integral feature of all humanities, and especially for philosophy. Philosophy itself and its method always remain as unforgettable objects of study for this discipline. Mathematics, as it is often claimed, takes a special third position between the natural sciences and the humanities. The very foundation of mathematics could be discussed by mathematical methods, but could not be solved. The primary questions of the foundational debate (20th century's first half) could be translated into mathematical or 'meta-mathematical' questions, and even the restrictions to this approach (Gödel) could be shown by mathematical means. There is no strict proof for the soundness of the axiomatic ground of mathematics, just intuitive arguments, but these are enough to continue with the work.

Prof. Nickel ended his presentation hoping that he was able to show the importance of taking the trouble to examine more closely this open plurality that is mathematics (because it cannot be understood as a whole), since it encourages reason against any form of naturalism (and naive monism), it shows a strange form of relatedness of human reason to freedom, and finally, it gives a model for the strange phenomenon of reflection.

Once the presentation had ended, the moderator allotted a few minutes for brief questions from the audience.

### *First Questions*

**Javier Leach: *Methodology to reflect on mathematics. What is reason?***

Javier Leach repeated that the meta-mathematics done in the 20th century have shown that a complete foundation of mathematics is not possible. He then asked that although

Nickel had said he is not mainly interested in a reflection on mathematics with mathematical methods, with what other methods then did he prefer to do it?

GREGOR NICKEL answered that his reflection (as shown in his talk) is done in two different levels. There is a sort of reflection within mathematics, in form of a technical program to formulate formulas and proof the rigidity of the very foundation of mathematics. However, he stated that without meta-mathematics, within mathematics itself, it does not work in an easy way. In a special context it was possible for mathematics to work on its own foundations with its own methods. On the other hand, philosophy does not have an easy progress, the same questions get asked again and again. Mathematics has a middle position. When mathematicians work on the foundation of mathematics by their own methods, there is an obvious circularity, so that one can show that the foundation would never be found by mathematical methods. But Nickel recommended the audience to take a step further back and ask what in the human mind is able to do such a special field of reasoning, which can show its own limitations. A question that would be better posed by philosophers [29].

JAVIER LEACH asked then what reason is for Nickel.

GREGOR NICKEL said that it all depends on the field. In a specialized field reason could mean formalization, calculation, defining rules and then obeying them... These would be some forms of reason, which get developed and applied by mathematics in a very broad field. But not speaking strictly as a mathematician, he would say 'reason' is an ethical phenomenon; it would be the ability to take the responsibility for one's own actions.

**JAVIER MONSERRAT: *The emergence of reason or freedom from nature in a naturalistic approach.***

JAVIER MONSERRAT stated first that mathematics is a creation of the human mind, but from a naturalistic point of view the issue would be why the human mind has the ability to create these abstractions. Human and other living beings develop biological structures in order to adapt to this world, which is a structural world. Animals adapt therefore their conduct to this structural world. In human beings there has emerged this capacity to abstract what a structure is; and out of this capacity the human mind has become able to freely imagine many structures. This ability and freedom would have emerged out of the evolution. This would be a naturalistic explanation of the human freedom that he asked for Nickel to give his opinion on.

GREGOR NICKEL confessed to be too much a Kantian to easily accept the picture where freedom emerges out of nature; he would plead to first divide the nature concept and the freedom concept. In his opinion, the story of evolving structures and ongoing adaptation to the complexity of the universe, understood possibly in much of a Platonic or a Pythagorean mathematical universe could be explained that way. The problem begins when you try to make this consistent. For instance, normally if you look into the evolutionary theory it has a simple concept of time, a continuum which is ordered like the real numbers, and this is a mathematical concept, and then again a sort of circle is established. We have an evolution process in time, understood as a real line, and then at a moment in time creatures invented or abstracted from nature look at nature and they

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[29] In his review of this summary Gregor Nickel has suggested to add at this point: «Here are some examples of other (apart from mathematical) methods (in terms of disciplines) for the study of mathematics: History, Aesthetics, Semiotics, Phenomenology, Kantian critics, Sociology».

see time as a real line and understand that they are in this real line. In this way once again a strange circle is established. If a consistent worldview is not pretended, one can talk about evolutionary *phenomena* that way, and this remains a *phenomenon*, but it is helpful to also consider the *noumena*. For instance, the invention of mathematics could be observed from the outside, but this is not all. There is a problematic division between freedom and nature, it is not easy to simply forget one, or have one explained as the epiphenomenon of the other. Prof. Nickel would plead for keeping them both.

JAVIER MONSERRAT suggested the word «complementary».

GREGOR NICKEL said he is not sure whether this is enough. In his opinion it would be just an indicator of a problem, pinpointing the question but not solving it.

At this point Javier Leach, as moderator, thanked Prof. Nickel and referred the subsequent discussion to the debate that would take place the following day, before giving the floor to the next speaker.

## III. WALLACH'S FRAMEWORK PAPER: COMPLEMENTARITY IS A USEFUL CONCEPT FOR CONSCIOUSNESSSTUDIES. A REMINDER

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ABSTRACT: We describe the concept of complementarity and argue that it is a useful concept for consciousness and other studies at the interface of conscious phenomena and physical reality. After outlining the history and source of the concept within psychology, we describe its place as a working hypothesis for the mind-brain problem. We then point out that generalized quantum non-locality could be of importance even for macroscopic objects. If this is so, complementarity would be the key-concept to understand EPR-like correlated systems.

KEY WORDS: complementarity, mind-body problem, quantum entanglement, consciousness

### INTRODUCTION

Implicit presuppositions are necessary albeit neglected preconditions of scientific thinking and human cognitive activities in general. Collingwood had argued already in 1940 [1] that at the base of any scientific endeavor are what he called absolute presuppositions. They stem from generally held beliefs about the nature of the world and the entities foundand expected therein. These presuppositions, Collingwood argued, arise from the general zeitgeist, which is a distilled product of human cognitive, social, artistic, technical and scientific endeavors of societies. They define what are to be considered appropriate and inappropriate scientific questions; they describe the basic ontology and lay foundations for methodologies and the prevailing epistemology. They usually change slowly and not by a rational process, but the change processes are determined by complex social situations. Toulmin [2] pointed out that this concept of absolute presuppositions incidentally lies at the base of Kuhn's outlook on the scientific process.

In that sense, science in general has been dominated by a set of absolute presuppositions which might be termed materialist-localistic. Some important presuppositions which many scientists would subscribe to are the following:

- Basic entities in the universe are material, or: Matter is primary.
- Relationships between basic entities are outer relations, or: Complexity emerges out of combinations of primary, material entities.
- Change is either completely random or has an efficient cause.
- Causes are contiguous. Those events which cannot be analyzed in terms of contiguous causes will eventually be reduced to simpler events which in turn can be analyzed in terms of contiguous causes.

From these positions about basic physical states follows one relating consciousness:

- Consciousness as a complex phenomenon is likely to be analyzable in terms of simpler events.

It is worth noting that these propostions are nearly identical with the basic tenets of ancient atomism as propounded by Democritos [3]. Surely there are more propositions which are necessary to characterize a modern scientific stance. And there are certainly many scientists who do have more complex and in some aspects differing opinions. But in a very general sense these propostions seem to be at the base of a modern scientific world view.

This so-called «scientific» world view or outlook is a set of absolute presuppostions which are notamenable to direct empirical, experimental or philosophical tests of truthfulness but show their usefulness only in a broader context. It is a question of considerable importance whether this world view will in the end be able to explain consciousness, and at present it is an open question. It has been argued convincingly [4] that materialist positions are inherently problematic. This argument is so much the stronger as it has arisen out of a materialist position itself. The price to be paid is dualism, which has been shunned by scientists, as it violates the principle of economy.

We propose here to hold on to a monistic position, not to a materialistic one, however, but to a neutral one, with matter and consciousness as two complementary aspects. This proposal is not at all new. In a sense, formally it was Spinoza's idea [5, 6]. The difference is that complementarity, being a principle rooted in modern physics, affords a conceptual framework which is different from Spinoza's and which, by virtue of its importance for the quantum mechanical formalism and thereby for entanglement or EPR correlatedness, might offer a road to empirical or even experimental approaches to the problem. Moreover, complementarity as a way of looking at the world is much older. A case can be made that the dogmatic formula which was the result of the concilium of Chalcedon in 451 A.D. that Jesus Christ is man and God in one person is an early example of thinking in terms of complementarity in the West, and that from a developmental point of view complementarity as away of looking at the world is a faculty which develops only after formal analytical thinking has been mastered [7-9].

## Complementarity

### *Complementarity 1: Basic Property of Material Systems*

Generally Nils Bohr is credited with having introduced complementarity as a necessary concept into the physics of our days [10]. He arrived at this notion when developing quantum mechanics together with Heisenberg, Pauli and others [11]. In its earliest form complementarity was introduced 1927 in Bohr's unpublished paper «The quantum postulate and the recent development of atomic theory» [12], pp. 91ff.], which was published in a somewhat altered version 1928 in «Nature». In this paper Bohrtalks about the fundamental complementarity of causal and space-time descriptions:

> «The very nature of the quantum theory thus forces us to regard the space-time coordination and the claim of causality, the union of which characterizes the classical theories, as complementary features Complementarity is a useful concept for consciousness studies. A Reminder of the description of experience, symbolizing the idealization of observation and definition respectively» [12] p. 91.
>
> «Nevertheless a complete account for the principal difficulties of satisfying the claims of causality within a space-time representation of atomic [microscopic] phenomena would seem to be offered only by the view that we are dealing here with complementary features of the description of nature» [12] p. 94.

The general idea which Bohr expresses here is that a causal picture of the world which refers to a particle view of matter and a continuous picture which is built on the wave model of matter can not be evoked simultaneously. «Wave» and «particle» are complementary aspects of matter. They can not be operationalized in the same experimental setting. In his paper «Licht und Leben-Light and Life» he expressed this idea in the following words [all translations ours]:

> «The continuity of the propagation of light through space-time on the one hand, and the atomic character of the effects of light on the other hand, therefore, have to be considered as complementary in the sense that each one of them expresses important aspects of the phenomena of light, which even though in

commensurable in terms of mechanics can never come into direct contradiction, since a thorough analysis of one or the other trait in the framework of mechanics calls for different and mutually exclusive experimental designs».

«Die Kontinuität der Lichtfortpflanzung in Zeit und Raum einerseits und der atomare Charakter der Lichtwirkungen andererseits müssen daher als komplementäraufgefaßt werden, in dem Sinne, daß jede für sich wichtige Züge der Licht phänomene zum Ausdruck bringt, die, selbst wenn sie vom Standpunkt der Mechanik aus unvereinbar sind, niemals in direkten Gegensatz kommen können, da eine eingehendere Analyse des einen oder anderen Zuges aufgrund mechanischer Vorstellungen verschiedene sich gegenseitig ausschließende Versuchs andordnungen erfordert» [13].

Bohr, thus, thought that complementarity is an irreducible and basic property of matter itself. Thisis what Fahrenberg [14], p. 54, had termed «Bohr 1»: descriptions in the same category, in this case, in the category of matter.

*Complementarity 2: Conceptual Framework for Pairs of Opposites from Different Categories*

Later in his life Bohr seems to have expanded the concept of complementarity to apply to all situations, in which a pair of opposite or incompatible concepts is used to describe one fact or event. Rather vaguely he says that living or social systems show characteristic traits which call for complementary descriptions:

«... that regarding analysis and synthesis in other branches of science we find circumstances which remind of the situation in quantum physics. Thus, the integrity of living organisms and the traits of conscious individuals and cultural communities show traces of wholeness, whose description calls for a typically complementary language… daß bei der Analyse und Synthese in anderen.

Erkenntnis gebieten Umstände vorliegen, welche an jene in der Quanten physik erinnern. So weisen die Integrität lebender Organismen und die Merkmale bewußter Individuen und kultureller Gemeinschaften Ganzheits züge auf, deren Beschreibung eine typisch komplementäre Ausdrucksweise fordert» [15] p. 7.

Bohr was quite sure that with complementarity he had discovered a generally applicable and broad epistemic and philosophical concept. Thus he says that the way in which emotions and cognitions are used in order to describe psychological facts is reminiscent of complementary relationships in physics [13]. In that sense Bohr expanded his concept of complementarity to all descriptors of situations, events or facts which were mutually exclusive and yet necessary to describe completely the entity in question «Bohr 2» [Fahrenberg, 1992, p. 54], thus refers to complementary descriptions which come from categorically different frameworks of descriptions.

It was in that sense that Fahrenberg [14, 16, 17], following v. Weizsäcker [18, 19], proposed the conceptof complementarity to describe the relationship between mental and physical events in order to describe the unity «human being», a proposal which is akin to similar ones introduced later but independently by Kirsch [20] or Elitzur [6]. According to this view conscious or mental events are not reducible, supervenient to or emerging from physical or physiological events, as proponents of different strands of materialism, functionalism, emergentism or epiphenomenalism would have it, but they refer to different aspects of one [ontologically neutral] substance, which however is only accessible through two complementary and in a sense mutually exclusive descriptions. They are nevertheless both necessary to describe what seems to be most elusive and most obvious to usall: conscious embodied mind or mindful body. Bohr himself seems to have favored a complementary solution to the mind-body problem like the one later proposed by Fahrenberg. It is, however, not complementarity in the original sense of the word, which is relevant here, but complementarity in a broader sense, referring to two descriptions from two categorically different systems of language or descriptions.

*Complementarity 3: A General Concept of Philosophy of Nature as a Supplement to Causality*

It should be noted for the sake of completeness that Bohr took complementarity to also be a general principle of Philosophy of Nature, supplementing or complementing causality. He calls complementarity a «consequent generalization of the ideal of causality» [13], p. 26. Already in his early writings he always connects complementarity with the irreconcilability of a causal description of nature with a wave description. A causal description relies on particle formulations, since it is by real or virtual particles that causes are mediated. A continuous description on the other hand uses wave models and field concepts, which treat particles not as physical material entities but as ideal points. When Bohr says that complementarity supplements causality, he in fact implies that there is another way of actively relating to the physical world than that of efficiently causal influence. If causally mediated change is by virtue of contiguous, material causes – following Hume's analysis – then effects brought about by a complementary class of events should be direct and immediate changes, may be due to direct conscious influences. Bohr at no place explicitly says so, but following the thought to its end seems to lead to this conclusion. If this is true, complementarity plays an even more important role, since it would be a termr eferring to a hitherto neglected side of nature: to consciousness in as much as it is the complement of matter, not as a separate substance in the old sense but as a complementary and irreducible description of a class of events. And following Bohr in that sense we should expect another mode of consciousness relating to matter, namely one which Bohr called the natural consequence of causality. It could be the case that direct interactions between mental and material systems as researched and reported by parapsychologists [21-25] are a class of events belonging in this category and testifying to what Bohr might have had in mind as another class of interactions complementing causality.

*Roots of Complementarity in Psychology*

It is interesting to note at that point that Bohr probably used psychological sources to coin his concept. Plaum [26] has researched Bohr's sources and found out that Bohr had manifold contacts with psychologists who used concepts similar to complementarity. On the one hand the philosopher-psychologist Harald Höffding, who was a close friend of the Bohr family, might have introduced him to the thoughts of Kierkegaard, who might have stimulated his own thinking. On the other hand, Bohr was a close friend of the psychologist Edgar Rubin. He had participated in perception experiments of Rubin's. Rubin is famous for his teasing perceptual figures which canbe seen in two ways – faces or vases, old witch or young girl – depending on our perception. Rubin called these perspectives «reciprocal». Furthermore, Bohr in an interview with the research team of Thomas Kuhn, Nov. 17, 1962, shortly before his death, conceded that he was introduced by Rubin to the work of William James who was the first to use the term «complementary» in the sense it was to be used later by Bohr. The locus classicus is from James' «Principles of Psychology», where he deals with what today would be called dissociative disorder [27]:

> «It must be admitted, therefore, that in certain persons, at least, the total possible consciousness may be split into parts which coexist but mutually ignore each other, and share the objects of knowledge between them. More remarkably still, they are *complementary*. Give an object to one of the consciousnesses, and by that fact you remove it from the other or others. Barring a certain common fund of information, like the command of language, etc., what the upper self knows the under self is ignorant of, and viceversa» [28] p. 204, italics added.

We have here what probably is the first mentioning of «complementarity» in the sense that two perspectives have to be taken which are mutually exclusive and yet are both necessary to describe a situation. Plaum [26] voiced the suspicion that Bohr was so reluctant to name his sources because he wanted to keep physics free from «soft» sciences like psychology. And yet it seems that Bohr has exported a soft psychological concept into hard physics.

There is, in fact, one passage in Bohr, which is reminiscent of his purported psychological sources in that it explicitly mentions the term «reciprocal» which was used by Rubin. In his text «Wirkungsquantum und Naturbeschreibung» [12], p. 205 [orig., Naturwissenschaften, 17, 1929, 483-486] which was published in German, Bohr writes:

> «We are acquainted with the necessity to seek out a complementary or better reciprocal description namely through psychological problems. In contrast the hallmark of the so-called exact sciences probably is the attempt to reach unequivocality by avoiding any reference to the perceiving subject.
>
> Mit der Notwendigkeit, zu einer in diesem Sinncomplementären oder besser reziproken Beschreibungsweise Zuflucht zu nehmen, sind wir wohl besonders durch psychologische Probleme vertraut. Dem gegenüber dürfte gewöhnlich das Merkmal der sog. exakten Wissenschaften in dem Bestreben gesehen

werden, Eindeutigkeit durch Vermeiden jeden Hinweises auf das betrachtende Subjekt zu erreichen» (p. 205, orig. 485).

In this passage Bohr explicitly acknowledges that it is especially with the conscious subject, or with consciousness in general, that complementarity becomes an issue. It is only with the interaction of a conscious observer with physical reality that the paradoxicalities arise quantum mechanics has become so famous for. It is with subjective consciousness that complementarity comes into play. Bohr seems to have intuited the fact that the ambiguity in the perception of flipping images, of delineating boundaries of personalities, and other observations of psychology, in short that the fact of consciousness introduces a situation which calls sometimes for complementary descriptions. It seems an extraordinary fact of the history of science that psychology with its reference to subjectivity as opposed to objectivity, soft as opposed to hard facts, has provided a conceptual tool for understanding matter. The tool is complementarity, and it was introduced at the price of vagueness and paradoxicality in the description of nature. And at the same time the concept of complementarity seems to be a bridge between material phenomena and conscious events. The difference is that while in psychology and what has been termed Bohr 1 and Bohr 2 «complementarity» is used metaphorically, while in physics/Bohr 1 the term has a rigid definition. It was, incidentally, the firm belief of the physicist Wolfgang Pauli, who was one of the leading figures in the developmentof the so-called Copenhagen interpretation of quantum mechanics [11, 29, 30], that physics would have to be complemented by psychology in order to reach a full understanding of matter. He had repeatedly expressed that fact in his letters to the psychiatrist Carl Gustav Jung with whom he had an intense exchange of ideas [31]. This exchange cumulated in the joint publication of a book entitled «Naturerklärung und Psyche – Explanation of Natureand Psyche» [32, 33]. This interesting dialogue which has only recently become available to a broader public and found some scientific interest [34] has tobe left aside at that point. Suffice it here to note that complementarity is at the very root of this dialogue: complementarity between psychology and physics,mind and matter, causality and synchronicity. It makes the proposition historically even more plausible and factually clearer: Complementarity is, at its deepest meaning, probably a concept relating conscious and material events in some regular way which we do not yet understand. This proposition seems to already have been in Bohr's mind when he introduced complementarity into physics. And this background is responsible for the fact that apart from a quite operational description of the term complementarity in the first sense of Bohr, it is not a well defined concept and its meaning changes depending on the level of generality it is used for. Therefore, an attempt at defining it is now in place.

*Attempting to Define Complementarity*

It is in itself an interesting fact that Bohr never gave a clear definition of complementarity. He gave descriptions in ever changing fashion, which somehow seem to contradict each other. This is due to the fact, as Fahrenberg [14] p. 54, has pointed out, thatthe term was used in the above described three senses. Atmanspacher [35] has mentioned the following three elements of complementarity.

1. A fact or situation is complementary if one needs an algebra of non-commuting operators to describe or formalize it, as it is the case with quantum mechanics. That is: depending on the sequence of measurements or applications of the operators the result is different. This is a more technical expression for what is commonly known by Bohr's expression that different experimental procedures are necessary to measure complementary aspects of a quantum object, and they cannot be performed simultaneously [36]. Classical examples are the operators of momentum and place which cannot give arbitrarily sharp values for the same particle at the same time. This is the essence of Heisenberg's uncertainty relation. But it can be extended to any pair of observables which are not indifferent to the sequence of measurements. Another way of stating this is that complementary statements describe different contexts of one and the same object. In each of these contexts observations and measurements can be made, which are not available in the other contexts. In each context there is a perfect definition and clear measurement values. But the full view of the object, all possible perspectives at once, can only be achieved by serially changing contexts.
2. Complementary terms are not just contradictory like a and not-a, but they are incompatible. They denominate descriptions which are mutually exclusive. If one description is used the other one is, at the same time, not available. Therefore,
3. Such relationships are formalizable only by a non-Boolean logic. A simple negation like «a particleis not a wave» is a statement which can be expressed by Boolean terms. Complementary formulations like «x is a particle and a wave depending on the measurement apparatus» can only be expressed by non-Boolean logic.

In that sense, we could attempt to define complementarity in the following way: Complementary statements are characterized by the fact that the measurements, observations or procedures necessary to form them cannot take place simultaneously, or that the properties described by these expressions cannot be realized jointly, and that the sequence of measurements or observations is decisive for the final result. A simpler way of stating this would be that complementary propositions have the same referent although they make at least two incompatible statements about it. Note that with complementary statements it is necessary to have at least two statements which are incompatible to characterize the referent, but possibly there could be more.

## Complementarity in Consciousness Research

It was in that sense that Fahrenberg [14, 16, 17] used the term complementarity. He proposed to view complementarity as a general principle which prohibits simple reductionist approaches in empirical research in psychology or psychophysiology. In his formulation conscious events and physiological events are not in either way reducible to each other but simply given facts which characterize the living being. They are complementary in the sense that they are both necessary to describe the living being, not reducible to each other, and delineate different empirical approaches: a hermeneutical-ideographic and an objective-nomothetic approach. Each one of the approaches has its own criterion of truth which belongs to its own categorical system. Neither of the categories is reducible to the other, easily translatable or superfluent. This is a proposal which in its consequence leads to a multi-methodological approach which has become if not standard then at least ideal in psychophysiological empirical research,at least in Germany [37]. But it could also be a guiding heuristic principle in that it prevents researchers from rushing at shortcut solutions to the mind-body problem which are fashionable because they seem so easy. Complementarity as a research metaphor for consciousness research would make the apriori assumption that mental and physical events are indeed in some sense related or even pertain to the same «substance», but need maximally incompatible procedures and propostions for their characterization, and therefore the attempt at explaining one (usually mental event) by some formulation of the other [usually physical events) is doomed to failure.

If this were the only reason for talking about complementarity within the realm of consciousness research, this would be a somewhat general and imprecise exhortation without much concrete consequence. There is, however, a sense, in which complementarity comes directly into play and which might be even experimentally relevant, which we now turn to: the generalization of quantum EPR-entanglement. This ascribes a central role to complementarity.

## Fundamental Nonlocality and the Generalization of Quantum Entanglement

It is well known that at a very basic level material entities behave holistically no matter how separate they are in space and time. This so called quantum entanglement or EPR-correlatedness refers to the fact that quantum mechanics treats material systems before any measurement is made as a whole with a multiplicity of possible states. Only when a measurement is made the wave function collapses, and the system exhibits definite properties. These properties are fixed at the instant of measurement. Observables that belong to the same quantum system exhibit correlatedness when measured, no matter how spatially distributed the system is [38, 39], producing nonlocal effects. This also applies to the temporal distributionof systems [40, 41]. While for the latter empirical tests are still awaiting their realization, for spatial EPR-correlatedness empirical tests have been carried out thanks to the pioneering work of John Bell, who by formulating his famous inequality laid the foundations for the operationalization of such a testing [42]. This test has been repeatedly carried outand proven quantum mechanics to be correct [43-46]. Nonlocal entanglement is the primary situation [47-50], at least for material quantum systems. Normally this entanglement is only visible after delicate experiments. Historically this is an unprecedented situation. For the first time in history a metaphysical question has been answered by empirical means [51]. Reality, before any conscious mind looks at it, is nonlocally entangled and a whole. Single entities, material objects (and perhaps single minds?) are secondary to that situation. They are created by what iscalled «measurement»: the taking notice of specificqualities.

Most people and scientists seem to think that this basic EPR-entanglement is irrelevant for our macroscopic world of minds and actions. Those who advocate a place for quantum mechanical processes inconsciousness research either adhere to an interpretation of quantum mechanics which makes consciousness primary, or they look to the many-worlds interpretation as an alternative [52], or they point out that at very basic levels of neurobiochemistry dimensions are so small that the quantum formalism has to be taken into account [53-56].

While this could be true, we do not want to follow these traces of thought. Although these approaches try to exploit quantum mechanical ideas for macroscopicphenomena, they still stick to the conventional compartmentalization according to which quantum mechanics has to do with the very small and subatomic realm, while classical approaches cover the regions above the Planck constant in spaceand time. What is even more interesting is a fact which seems to have gone rather unnoticed and which has been pointed out by Primas recently [57]: Landau [58] (as quoted by Primas [57]) has shown that EPR-correlatedness is generalizable. That is to say that entanglement need not be confined to microscopic systems but could come into play in systems of any size and make-up provided three conditionshold jointly:

1. There exist two systems which are kinematically independent.
2. Each of the two systems is well defined.
3. In each of the systems there is a pair of observables which demand, for their description, an algebra of non-commuting operators.

The last condition could somewhat loosely be reformulated into:

3a. Each of the two systems contains at least one set of observables which are complementary to each other in the sense that their descriptions are maximally incompatible with each other and require mutually exclusive experiments or empirical procedures to measure or verify them.

Primas [57] has pointed out that the algebraic formulation of Landau [58] does not presuppose that the two systems have to be material. Following a foot note of Jung's [32], p. 85, note 7, in which Jung states that the relationship of mind and body could be what he called a synchronistic one, Primas [57] speculates that the generalized formulation of the EPR-correlatedness also allows for two different systems, a material and a non-material system, to be related.

We would like to point out that possibly even 3b holds:

3b. Each one of the subsystems contains one half of the pair of incompatible observables.

In that sense complementarity comes into play again in a different sense. Two systems which together can be characterized by, or jointly contain, a set of incompatible or complementary variables are EPR-correlated, if they are kinematically independent and well defined. While all these terms are quite well understood in a physical sense, relating to physical systems, it is not known what this would mean on a more macroscopic level, pertaining to biology or psychology. While some authors have already speculated that quantum-entanglement might have been used by biological systems in the course of evolution in order to maximize their evolutional gain [59], and while there are some general statements that EPR-correlatedness probably has some impact also in macroscopic systems [60, 61], there is no systematic research which has followed along the lines suggested by Landau[58] or Primas [57].

One serious problem pertains to the fact that while in quantum mechanics everything is well defined and a precise mathematical formalism is available, no such precise formulations are available in «softer» sciences like psychology or consciousness research. Thus, we do not know what it means for two macroscopic systems to be well defined, or to be kinematically independent, let alone to contain a set of observables requiring formalization in terms of an algebra of non-commuting operators. Thus only a few speculations can be made at this point.

## Speculations and Tentative Exemplifications

In the polarization experiment to test EPR-entanglement there is one system with two separate subsystems, each of which can be described, e.g. by spin directions which are mutually exclusive, or complementary in the adopted terminology. In analogy, the human being could be viewed as the system comprised of two separate, but entangled subsystems. Entanglement would be active until a «measurement» is performed at which both systems are found to be in corresponding states. This so far is not more, nor less, than a rediscription of Leibniz' famous examples of two clocks going in harmony or preestablished harmony of inner and outer processes [62] 65f.:

> «Souls follow their own laws, ..., while bodies follow theirs, namely the rules of motion. Nevertheless, these two entities of completely different kind meet and are coordinated like two clocks, which have been perfectly set in the same way, although they may be of totally different making. It is exactly this which I call preestablished harmony.
>
> «Die Seelen folgen ihren eigenen Gesetzen, …während die Körper ihrerseits ebenfalls den ihrigen, nämlich den Regeln der Bewegung, folgen. Trotzdem

> treffen diese beiden Wesenheiten von gänzlich verschiedener Art zusammen und entsprechen einander wie zwei Uhren, die wollkommen in derselben Weise reguliert worden sind, wenngleich sie vielleicht vong änzlich verschiedenem Bau sind. Eben dies aber nenne ich die prästabilierte Harmonie».

The difference is that in the case of generalized EPR-correlatedness there is a more basic principle at work which, at least generally, is amenable to empirical research and testing. The principle is that in both systems sets of non-commuting observables, which we translate into complementary variables, are regulating this coordinated behavior. The problem is that we do not know what this could mean, apart from the known quantum mechanical formalism. One line of thought could be to analyze all organismic processes in terms of different sets of complementary terms – «complementary» for the time being taken in the loose sense as described in this paper. For instance, every single organismic process can be characterized in terms of individuality or singularity and connectedness. No matter whether we look at molecular processes, at the cellular or organ levels, all processes can be described on the one hand as singular, individual events. But all these singular, individual events are at the same time regulated by top-down principles which restrict and channel these events. A neuronal event, for instance, can only be seen in its direct connection to the whole nervous system. The same is true for immunological processes. They always have to be analyzed in terms of single events on the one hand, which are events within a larger system on the other hand. Thus «individuality» and «connectedness» could be a pair of general terms which could apply to many systemic levels exemplifying a set of «complementary» variables.

«Individuality» and «connectedness» both fulfill at least at first appearance some requirements for terms standing in a complementary relationship with each other:

1. They cannot be «measured» or seen in the same experiment or measurement. In order to measure individuality, one has to analyze an event as single, thereby stripping it of its connections. In order to look at connectedness, one would neglect individuality and synthesize single elements to a larger compound.
2. Depending on the sequencing, results are different. Any individual seen first and foremost in its role as individual is and appears differently from the same individual taken as an element in an interconnected system. This is so, because in an interconnected system the complex relations hips form and change any part of it continually, thereby introducing an irreversible temporal order. Therefore, every individual is different from moment to moment. This is a striking resemblance to the fact that the generic definition of non-commuting observables is the difference in mathematical results depending on the sequence of measurements.
3. They also seem to fulfill one criterion mentioned above: They are incompatible at first glance, and yet they are needed to describe any living system completely. There is no single system in the whole universe which

is disconnected from its surroundings and thus a true individual (except perhaps the whole universe). Individuals only make sense and take shape in connection with other individuals. On the other hand it is utterly senseless to talk about the connection of every thing with everything, or totality, or wholeness, unless it is specified what parts a whole or totality exists of. Individuality and connectedness are not just contradictory terms. They are mutually exclusive, and yet necessary to describe any system.

4. It is of considerable interest that these terms are so general that they need not be confined to material systems or entities in the strict sense. They could also refer to mental systems, like semantic, semiotic, or social systems.

In other frames of reference one would probably opt for different notions to describe a unit of analysis, like a human being, or a group: They could also be termed «individual» and «society» when referring to sociological or social-psychological systems, or «freedom» and «responsibility», when considering the realm of moral philosophy and ethics. The same basic relationship seems to be at work in many domains: In personality theory there is a long-standing debate about the primacy of traits, representing the individual, and states, representing the environment, in which the individual is embedded [63]. In genetics the debate is about the primacy of genes and the modification of their expression by a given environment [64].

If this is plausible, then we have a set of complementary variables in each system. For these two elements are present in every system, specifically in the human organism and in consciousness. All physiological processes, whether they are metabolic, immunological, hormonal or neural signaling processes, depend on this relationship that single individual events are necessitated and modified by the organic whole of the organism which they in turn change and modify. Thus, the individual process is determined by and at the same time determines the whole. The same is true for the first-person account of consciousness. Single qualia always are qualia ofa certain specific perception, which is a perception only by virtue of its embeddedness in the whole cognitive structure.

In a broader sense, complementarity as envisaged by Fahrenberg holds also between the mental and the physical systems. These two systems are in a complementary relationship, too. They are both maximally incompatible descriptions of the living human being. One has to use different and in a sense mutually exclusive experimental or empirical approaches, in order to «measure» them. Thus, the human being in totality can be characterized as a system containing a set of complementary «variables» or «observable», the mental and physical system.

One prediction resulting from this analysis would be that we should observe EPR-like correlated events in any subsystem which is temporarily or other wise connected to a human being to form a higher order system, and the other way round. This could happen if the other is also a system describable in terms of complementary variables, the boundaries between the two systems are temporarily suspended, and thus two sets of complementary variables are present. This would be the case, for example, when two human beings enter any sort of relationship, which delineatesthe dyad against the outside as one system. It is one of the purposes of rituals to draw a distinction between inside and outside thus delimiting, at least temporarily, a higher order system. The prediction would be that whenever human beings meet within such a ritualistic context, which joins at least two persons into a supersystem, they are EPR-like correlated, and entrainment ensues [65, 66]. This could be the basis for the well known but little understood phenomena of transference in the psychotherapeutic, especially psychoanalytic setting, for ritualistic or placebo healing, and possibly for experimenter effects in science.

«Transference» denotes the simple fact that in a psychotherapeutic context the therapist [and the clientor patient] experiences emotions, body feelings, and trains of thought, which are not «his» or «hers» but his or her patient's. It is part of the therapeutic training, at least in the traditions deriving from psychoanalysis, to learn to discriminate between personal and other contents, and to use the «transferred» material accordingly. In the classical psychoanalytic setting the material is used for interpretation. It is fed back to the patient as the patient's own, not yet acknowledged, feelings, affects or thoughts, thus enabling the patient to own the material. While this process is practically well understood and frequently used, it is not at all clear theoretically. Usually one would invoke subliminal signals or perception of hidden cues to understand how such transferences arise. This does not seem to be a sufficient explanation for seemingly absurd, unfitting and spontaneous mental events, which are frequently experienced within the context of psychotherapy. An analysis along the lines proposed in this paper would be more fitting to the empirical phenomena.

Ritualistic and placebo healings have been reported repeatedly. While some can be understood along conventional lines by expectancy effects [67,68], there are strange phenomena which defy explanations by known psychological mechanisms: Prayerhealing sometimes seems to be effective also in a double blind setting, where both groups had the sameexpectation [69-71]. In clinical drug trials across several diseases, therapeutic effects in the placebo group are highly correlated ($r = .59$ to $r = .89$) with therapeutic effects in the drug group [72, 73]. While the traditional model would predict that this correlation between drug and placebo-groups reflects the expectancy effects, we could in our own research find no correlation whatsoever between a measure of expectancy and therapeutic effects in the placebo and drug groups [74]. It might be promising to analyze these effects in terms of correlatedness as advocated here.

Finally, experimenter effects are well known in behavioral science [75]. They refer to the fact that experiments sometimes are biased in the way experimenters expect results. In the traditional analysis they are taken to be due to insufficient blinding, such that experimenters know about the desired outcome and subliminally convey this knowledge to the participants, who perform in the socially desired way. While this is certainly a good way of describing experimenter effects in unblinded research, it is difficult to understand such effects in double-blind experiments, where no one has a cue. There have been occasional reports of experimenter bias even in double-blind drug experiments. A classic in that sense are the two studies of Uhlenhuth [76, 77], in which blinded doctors had different results with a drug and a placebo according to their belief, although they could not have known which patients were treated by which substance. We found in a blinded experiment of dowsing that, although on average volunteers were unable to discern poison from water by dowsing, they were significantly more often to do so when instructed by a particular, but blind experimenter [78].

These and probably many more anomalies could be analyzed as instances of generalized EPR-correlatedness, in which a system exhibiting complementary variables – here: a mental and a physical system – is entangled with another system – here: another human being – by virtue of a systemic boundary whichis temporarily erected by a ritualistic context, such as a formal trial, an experiment or a therapeutic setting. This would also make plausible when and how anomalous correlations between consciousness and material systems, as researched by parapsychologists, can occur, without violating any known physical laws and without running contrary to scientific orthodoxy.

What we have proposed so far is a general model, which is neither new nor our genuine invention. This is why it is called a reminder. We suggest that the model could be a useful metaphor and framework, and we have elaborated into a few directions how it could be fruitful. It is, however, a future task to operationalize and make concrete the very general predictions and to test these predictions in empirical research. It could well be that this framework could be useful for understanding consciousness-matter interaction of any degree and two-system-interactions in general, without having to resort to reductionist approaches, and without getting stuck in pure dualism. Complementarity seems to be a notion of considerable theoretical, predictive and explanatory power, when set free from its quantum mechanical technical domain and expanded from there to where it originated: to psychology and the study of conscious phenomena. It affords a redescription of well-known positions in the reflection on the mind-body-relationship in a more adequate, modern language.

In sum: The proposition made here is to analyze the relationship of conscious mind to living body interms of generalized EPR-correlatedness. This predicts that the two systems, which are well described, kinematically independent and yet belonging together, are EPR-correlated, if they contain or exhibit each a set of complementary variables. We have proposed to take individuality/singularity and connectedness as general categories of physical and mental systems. If this analysis is accepted then mind and body, following a suggestion of Jung and Primas [57], can be seen as two entangled systems. Extrapolating from there, every human being can be seen as a system containing two complementary variables – mind and body, consciousness and physical system. If this is so, the same applies for two (or more?) human beings joined together by any system-generating mechanism, and probably also for human beings and physical systems, as long as these physical system also exhibit signs of complementarity. While not subscribing to reductionist approaches, this proposal can enlarge our understanding how seemingly not causally related systems can nevertheless be in intricate communication.

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## IV. SESSION PROCEEDINGS

### PRESENTATION: GENERALIZED ENTANGLEMENT, A NON REDUCTIVE OPTION FOR PHENOMENOLOGICAL DUALIST AND ONTOLOGICAL MONIST VIEW

#### *Introduction – mainstream materialistic model*

Prof. Walach began his presentation by summarizing the mainstream view of the materialistic and reductive model that assumes that material entities are the only important things in the universe and everything else is derived there from, such as mind and social systems can all be reduced from material interactions. Most importantly from *local* interactions that imply *contact* between elements transferred by signals. This reductionist point of view produces a materialistic universe and Prof. Walach claims that our basic presuppositions – such that only material entities exist – dictate precisely what we can see. He believes that philosophy should be critical of such presuppositions in order to enlarge our world view as is his endeavour.

A striking historical example that our theories dictate what we see is when William Harvey discovered the heartbeat in the 17$^{th}$ century. This model of the heart as a pump was in stark contrast to the Aristotelian concept of blood circulation by convection, with the heart acting as a warmer and the brain a cooler that prevailed after the Arabic medicine had discovered the heart as a pump. The leading medical and philosophical thinker of that time, Parisano, denied this possibility and declared: «we cannot hear the heartbeat, and nobody is in Venice, who can». They could not perceive the heartbeat, nor hear it, because they did not have a theory to describe it. Prof. Walach affirmed that this shows that a theoretical model prefigures perception.

## 1. Weak Quantum Mechanics

At this point, Prof. Walach invites the audience to shift their perception and adopt the new view point he will present and to observe the difference. He believes that a new theory and paradigmatic model to understand the world, in order to understand holism, non-mechanistic order, and a non-reductionist view of mind and consciousness is needed. In the publication of «Weak Quantum Theory» [30] (WQT) they presented a model that predicts a generalised form of *entanglement* – a concept established by Schrödinger in 1935, meaning that elements of a system that belong to each other and hang together are correlated *without* the exchange of signals. This new model proposes an entanglement-like non-local correlation as is known from quantum physics, but that is not quantum correlation. It is extrapolated as a basic, complementary mode of relatedness, that is regular and probably law guided but different from causal relatedness.

Walach explains that it comes out of the formalism as a sort of prediction or result of this formalism that predicts non-local interaction without the exchange of energy; these are not left over quantum correlation, but generalized correlations that would be predicted. Briefly, WQT is an algebraic formalism given the same treatment as quantum mechanics (C*-algebra), where they have dropped all definitions and all precisions (e.g. Planck's constant) and shrunk the whole formalism to its bare core. It can be shown that quantum mechanics can be recovered, but the bare core of the formalism of WQT means that it handles non-commutative observables or non-commuting operators.

The problem of commutation was mentioned by Prof. Poli during the first session, where in science commutative algebra is common. In real life, things are more complicated and are rarely commutative. So this is an element that is important to take into account, the sequence is very important and there is a definite way to do things. In quantum mechanics non-commuting elements are defined as complementary elements. Complementarity is at the core of quantum mechanics and a non-commuting algebra needs to be used, and this is precisely what is left in the formalism of WQT. When this is done it predicts entanglement in macroscopic systems regardless of make-up, size and ontology.

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[30] Atmanspacher, Römer & Walach (2002), «Complementarity and entanglement in physics and beyond». *Foundations of Physics*, 32: 379-406.

## 2. Complementarity

Complementarity is defined as *two descriptions for one and the same object or situation that are maximally incompatible, yet need to be applied conjointly for a full understanding*. This concept was introduced by Niels Bohr and was defined formally in quantum theory. It is loosely defined in WQT and in the real world. We are normally not used to dealing with this concept due to the Aristotelian logic of *either-or* that does not deal with complementary elements that are necessary for quantum mechanics, which is why it was created to begin with.

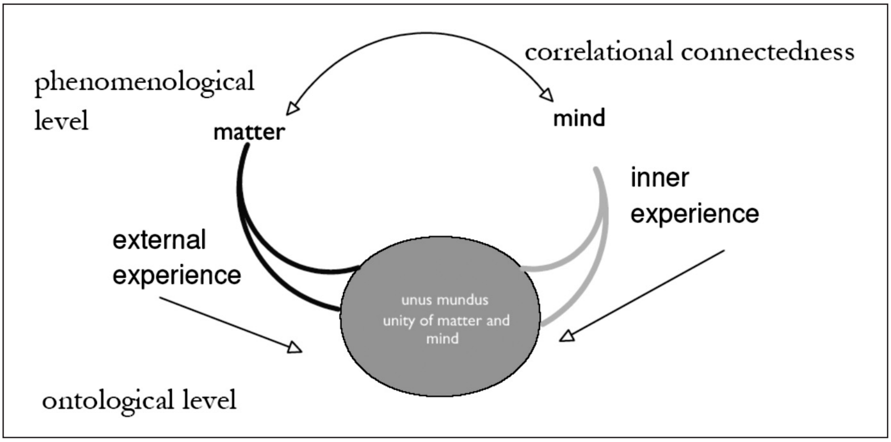
Prof. Walach then proceeded to give examples of Complementarity. First of all he mentioned the complementary variables in quantum physics that are well defined and known, such as: location*momentum or time*energy. You can measure one, but you then lose the precision of the other. Other examples that could be more freely established are: individual*community or separation*connectedness that seem to be mutually exclusive. Structure*freedom is an example from the educational context that is well known as is form*content from literature and perhaps love*justice from a legal aspect.

In this famous ambiguous figure of E. G. Boring represented above, it is possible to see either a young woman or an old woman. It might be difficult to decide what are the different components represented in each of the interpretations: nose, hat, feather, etc. And even if they can be identified, one's mind seems to impose each interpretation rather than being compelled by the «perceptual evidence». These two images seem to be complementary images of the same drawing.

## 3. Complementarity of mind and body

Prof Walach then introduced the following representation as a summary of the complementarity of mind and body [31]:

[31] Walach & Römer (2000), *Neuroendocrin Letters,* 21: 221.




Complementarity can be used very well to describe a physical and a mental representation of one nature. The claim is that there is one unitive nature, which may be non accessible, which shows in two modes – physical and mental – that are correlated.

Other scholars have worked with this terminology such as Spinoza, C. G. Jung, Pauli and Leibniz who is quoted below:

> «Souls follow their own laws, ..., while bodies follow theirs, namely the rules of motion. Nevertheless, these two entities of completely different kind meet and are coordinated like two clocks, which have been perfectly set in the same way, although they may be of totally different making. It is exactly this which I call pre-established harmony» [32].

C. G. Jung and W. Pauli also developed similar concepts. Wolfgang Pauli, probably one of the most important prodigies in physics – who wrote an authoritative article on relativity at the age of 18 that Einstein praised – was also in psychological trouble and entered in contact with C. J. Jung for psychotherapy. A dialogue ensued through letters between them in 1930-1958 where the concept of the phenomena denominated *Synchronicity* was developed. This is a familiar concept to everyone; for example when one has a problem that is difficult to resolve one often encounters a book, receives a letter, or receives help that guides one to a solution.

They wanted to find a way that this could be used and integrated to our physical knowledge, but discovered that it can't. They believed that there could be something complementary to causality and drew up a quaternity represented above [33].

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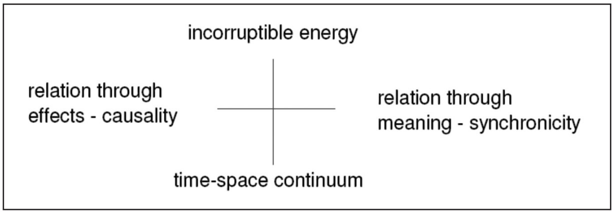
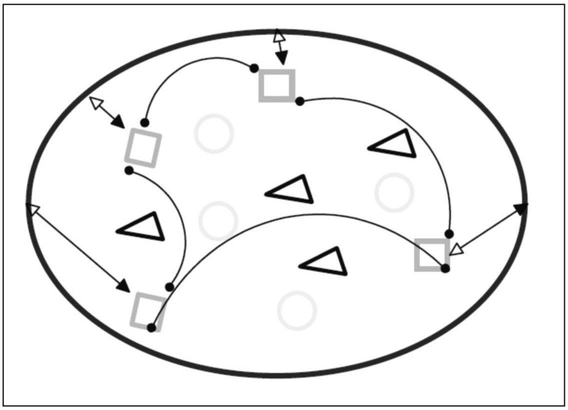
[32] Betrachtungen über die Lebensprinzipien und die plastischen Naturen, Collect Works, p. 65f.

[33] Jung in a letter to Pauli, 30/11/1950. MEIER, A. C. (Ed.), *Jung-Pauli Briefe,* Springer, 1992, p. 64.




Returning to entanglement – the notion from quantum physics – Prof. Walach proposed a system such as the one represented graphically below:



In that system there are various elements. If the description of the elements (squared) is complementary to the description of the whole system, then entanglement ensues between all those elements and not between the other ones. Imagine you pull one of those squares, every other element would move in a coordinated manner without signal interchanging between them. That is the notion of entanglement.

It is very clear from quantum physics that our nature is constructed like that. There have been numerous experiments proving that in quantum physics proper, entanglement is a fact. Furthermore, in the frontier sciences, such as quantum computation, they are all built on entanglement. The difficulty is that it is a fact in very restrictive systems. The system has to be isolated against the environment or entanglement decays. Walach affirmed that this is why tables and other material elements exist and can be manipulated.

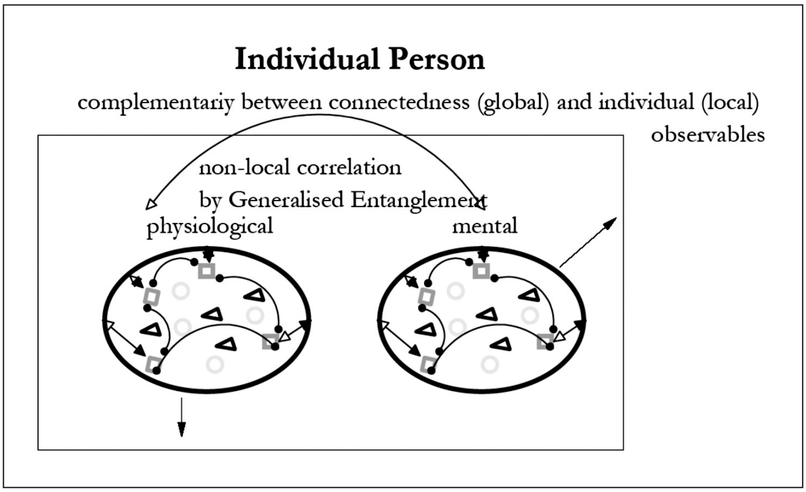
## 4. Generalised Entanglement as a Coordinating Mechanism

The WQT model proposed would predict that, if true, we should also observe non-local co-relatedness in all sorts of systems as long as the formal requirements hold: complementarity between global and local variables. Recalling the list of examples given above, such as individual*community, then we can see that this is a very generic definition. Our expectation would be that in every group where you have group cohesion – a system formed against the outside world that unites individuals – you should expect some form of non-local correlation between these individuals. Members of a family and anyone in close social contact often experience this in different ways. This model allows for the reconstruction and understanding of this phenomenon.

Prof. Walach presented this as a coordinating mechanism for understanding how mind and body could be correlated. There is a general connectedness between mind and matter through the system or generalized entanglement and this could be described as follows:

> Step 1: A formal treatment of a system that through generic symmetry breaking, a distinction arises between mental and physical systems, as broken time-reversal symmetry[34]. The result is two distinct descriptions of the same reality or nature.
>
> Step 2: Each of these systems is governed by generalised non-local entanglement correlations. The claim is that what we know as causal descriptions are probably secondary and derivative of that.

Therefore, there is a complementarity between process (global) and structure (local) or connectedness (global) and individual (local) observables, ensuing in non-local correlations between the elements of a system. That would hold for all levels of systemic description. For example: between elements of a cell, different cells within an organ, different organs of an organism or physiological coordination. The same would be true of mental coordination, thoughts, wishes, fantasies, imaginations would also be correlated. This can be represented as follows:




[34] Atmanspacher (2003), *Biosystems,* 8: 19.

The correlation would hold between elements of the system, that is between the physiological and the mental systems there would be non-local correlation. This is how we could envisage the whole coordination of the human organism. That is, everything coordinated in principle by non-local correlations and as a result of this causal descriptions could arise.

This can continue by establishing correlation between individuals and the whole of a group.

## 5. Spirituality: Connection between Individuals and the Whole

Prof. Walach then added that this model can be used as a reconstruction of spirituality. If spirituality is defined as an individual being oriented towards a transcendent whole, then you can use non-local correlation between individuals connected in one whole to conceptualize it. The more the individual connects to the whole, the greater the correlation between the elements becomes.

## Conclusion

To summarise, Prof. Walach makes a bold claim by postulating an axiomatic system out of which a generalised form of non-local correlation could be derived and it could be expected to be operative in systems of all kinds.

It can be used to reconstruct the relationship between mind and body without having to result to dualism, which is a very important point. It is not necessarily a dual system in the sense that both are ontologically fixed as in Cartesian dualism, but they are phenomenologically distinct so they are categorically distinct and can be distinguished as different realms. It is not necessary to reduce one to the other as in classical neuroscience, but they both emerge from a generic – perhaps transcendent – ground and this is the process where you can coordinate these two realms via a mechanism of generalised non-local correlations, which once again should not to be confused with quantum correlation.

Turning this around, Prof. Walach claimed that perhaps the whole of nature is like this in a much more general manner, yet it is only in physics where it could be framed, calculated with precision which allowed for the discovery of entanglement. If you use this model as a potential view point to look at nature, you may discover different phenomena.

Once the presentation ended, the audience had time to ask questions. The debate began with the translation into Spanish of *entanglement*, which was agreed to be «entrelazamiento». This concept that was coined by Schrödinger was «Verschränkung» and it implies intertwinement of two entities or concepts that are not easily separated.

*First Questions*

**ADOLFO CASTILLA: *On the causal relationship between complementary phenomena.***

ALDOFO CASTILLA asked whether or not complementarity implied a cause-effect relationship.

HARALD WALACH answered that it didn't and clarified that it means that two distinct perspectives are needed to describe one thing.

ALDOFO CASTILLA then asked about the relationship between the complementary phenomena, if it was electromechanical or Hertzian waves.

HARALD WALACH stated clearly that there wasn't any signal and that the model rationally reconstructs a relationship where no signal and matter is involved. He went on to explain that there wasn't much empirical proof to demonstrate it and that it was based on reasoning, which could or not have meaning for each individual.

ALDOFO CASTILLA expressed that he felt that there was a missing link and asked Prof. Walach to further explain this.

HARALD WALACH agreed on the need for an analogue of the empirical experiments that convinced physicists that entanglement was real. When Bohm established his formulation or *nonlocal hidden variable theory*, Bell was then able to translate it into an experimental set-up out of which his inequalities emerged. This implies that if a quantum system is not correlated, it should not exceed Bell's boundary conditions. Even if there may be principle problems, they are trying to find an equivalent experiment for their model.

ALDOFO CASTILLA ended by asking if Prof. Walach was aware that scientists would be sceptical and refute this model as not being *scientific*.

HARALD WALACH answered that *scientific* was a difficult term and implied a set of accepted rules. Their model is based on scientific reasoning that aims to extend the rules or boundaries of what are *scientific* rules, which if not accepted would be a very limited view of science.

**JAVIER MONSERRAT: *Why is entanglement the only quantum phenomenon considered?***

JAVIER MONSERRAT recalled that the mind/body problem has been one of the most important aspects of the philosophical, scientific and psychological discussions. He agreed that the best way to find an explanation would be in quantum neurology in connection with quantum mechanics. In order to explain the mind and the phenomenological world, you would have to explicate the basic phenomena: quantum coherence, quantum superposition, quantum indetermination and the Einstein-Podolsky-Rosen (EPR) effects or action at a distance, which is a consequence of entanglement.

Monserrat asked why Walach only referred to the last effect and entanglement when as far as he knew, the Hameroff-Penrose hypothesis along with the ideas of David Bohm established a relationship between quantum mechanics and the human sciences and mind that is based on these four physical phenomena. He also asked for an insight to this problem and why they didn't take into account quantum coherence and superposition that are in favor of their ideas.

HARALD WALACH responded that quantum applications to neurological studies were important ideas but that they have not considered them in their model as it was already complicated as it was. He stated that there were some categorical problems and that although they are very relevant, they might not really be needed and would not help in bridging the gap between physical and mental phenomena. He would also agree that there were quantum effects going on in the brain, although it was currently being debated if the brain was a system in which they could occur. Prof. Walach expressed great respect for Stuart Hameroff and the clever idea to bring in Fröhlich coherence yet it was not necessary to make the point he wanted to. Finally he pointed out that it would leave the model more open to critique over details about the brain being too wet and noisy to sustain quantum correlations.

**SARA LUMBRERAS:** ***Is there experimental evidence of synchronicity?***

SARA LUMBRERAS commented that being scientific and pushing the frontiers of science was not necessarily reduced to wild speculation and that a priori one could find empirical evidence that points to such a model being more representative of reality. She asked if there was anyone attempting any serious research on these phenomena, such as synchronicity.

HARALD WALACH responded that there was very little research being done on synchronicity. He commented on two studies that were trying to fix some quantitative description of synchronicity, but remarked that this was very difficult since the base line probability of the events in the universe are unknown.

They were trying two things: first they are bringing in experts to study the viability of the idea (theoretical clarification) and part of this process is to set up a think-tank to try to come up with a macroscopic analogue of Bell's experiment, which would be the ultimate aim. He has also published a series of papers about his model being plausible to reconstruct phenomena that are difficult to understand such as homeopathy, spiritual healing or to use it to redescribe the concept of *chi* in Chinese medicine. The next step would be to find an empirical model.

**JENS DEGETT:** ***The difficulty of proving a theory without empirical evidence.***

JENS DEGETT commented that as a journalist he liked to ask difficult questions even if the answer is not always understood. To illustrate this he mentioned that during the UNESCO Conference on Niels Bohr the experts of quantum mechanics were mentioning the classical wave/particle (double-slit) experiment and the impact of the observer on the results of the experiment, such as by having your microscope out of focus. When he asked them a hypothetical question about the possibility of measuring a phenomenon in such a complicated way that you needed three days to obtain the result and the implications this would have on the results, the experts couldn't handle this because it was beyond the physical observation as it implied time and the understanding of what is information and when it is acquired. He then stated that even if entanglement was true, it might be impossible to prove.

HARALD WALACH expressed agreement with this statement.

JENS DEGETT remarked after his observation, that the only way to prove a theory was by experimental proof and insisted on the difficulty that this presented. He asked how they could construct an experiment that would work.

HARALD WALACH acknowledged that he didn't know. The tricky part is that of knowing the basic probabilities of the system and whose singularities are undetermined. This is viable in quantum mechanics, but in the generalised case of their model, it could be that the whole universe was the system and there would never be enough empirical evidence.

**Christine Heller: *The use of phenomenological data as empirical proof of entanglement.***

Christine Heller commented that how can something as frequent as entanglement between members of the same family be denied and asked if entanglement can be sustained or whether it would collapse such as in a table.

Harald Walach agreed that if phenomenological data was used then it is very clear. Of course the problem is that this doesn't count very much in hard sciences so an epistemological shift is needed. This is another topic that can be discussed. As for the sustenance of entanglement, in the classical or physical case, it is a property of a system that is isolated and is sustained as long as it remains so. In the generalised case, you only observe it under certain circumstances and in isolation. He expected it would not go away when ritual ties exist – such as in psychotherapy and in families – but it would disappear if they were disturbed.

**Miguel Lorente: *The possibility of a model with more ontological compatible concepts.***

Miguel Lorente observed that the difficulty of the model is that in quantum mechanics there are observables and operators, and a well defined situation of experiments, yet the model extrapolates this to a new reality where there is more than what quantum mechanics describes and quantum correlations are lost. He asked if they had considered making a model between more ontological compatible concepts to analyse complementarity. Would it be possible to make an ontological concept of physics and sensations with the same type of correlation but from the same metaphysical point of view?

Harald Walach was uncertain if he had completely understood Lorente's question. He clarified that what they were doing was extrapolating a concept that is used in a very clear way in another system and he was claiming that this is reasonable and rational and can be a source of inspiration. They have produced an axiomatic framework to connect classical quantum mechanics with this framework. He added that you can argue that this isn't scientific, which may be true, but it is a generalisation of the deep layer of concepts to a unitary reality. To us it only appears as mental and material phenomena, yet there is a need to go beyond the common sense notion of natural science that only recognises material reality and states that everything else is derived from it. Material reality is derived from a deeper unity out of which mental phenomena also arise. Hence, the model is used to describe how different aspects of reality can be co-ordinated without a signal interchange.

**Agustín Udías: *On the ontological reality of entanglement.***

Agustín Udías continued with the last question and asked if this was just an analogy to explain phenomena or if they were implying some kind of ontological reality to entanglement.

Harald Walach answered yes to both. He explained that they are using analogous thinking to imply that non-local correlations exist outside of quantum mechanics.

Agustín Udías asked if they were making an interpretation of quantum mechanics to give it a reality aspect to quantum entanglement.

Harald Walach replied that they were.

Agustín Udías warned that they should be careful as one thing is quantum mechanics and another is the interpretation that should be kept separate.

Harald Walach said that they were aware of this. They are not quantum correlations, because this has a particular meaning that they were not extrapolating to everything, as it would be useless. But, non-local correlations can also be found in other systems which are analogous to the situation in quantum mechanics. These correlations are real just in the same sense as quantum correlations are.

AGUSTÍN UDÍAS then stated that the second part was very debatable.

HARALD WALACH replied that of course it was.

AGUSTÍN UDÍAS mentioned an article he had read in the magazine Physics that cautioned physicists to try not to make a reality what is really an instrument to explain certain characteristics of observables.

HARALD WALACH acknowledged and agreed with what Udías was saying. Physics is an instrument for modelling reality and is not reality itself. So in that sense, this is also just a model that claims that non-local correlations are real phenomena. Whether there is another model that might explain these correlations completely differently is another issue. You can use this model to describe phenomena that can be observed rationally and reasonably by connecting it to scientific reasoning. In five hundred years from now there might be another theory that would explain it from a completely different perspective.

AGUSTÍN UDÍAS asked if he was not satisfied by saying that it was *just* a model.

HARALD WALACH replied that he was, as long as this implied that the reality described by the model was considered as real.

AGUSTÍN UDÍAS specified that only certain aspects of it.

HARALD WALACH agreed.

### ADOLFO CASTILLA: *Difference between the model and «common wisdom»?*

ALDOFO CASTILLA asked about the difference between their explanation and what is called «common wisdom». It seems similar except from the use of particular words such as non-local correlation, entanglement or complementarity.

HARALD WALACH expressed agreement concerning trivial examples of everyday life, where the terminology to describe what happens in a natural world environment is not needed. But, when it comes to understanding a phenomenon scientifically or theoretically in connexion with the rest of theories of a multitude of other phenomena, then you need a theoretical model. The explanations of some phenomena are not straight forward and are frequently debated. In these cases there is a need for a scientific description and this model could cover a large variety of phenomena.

### JAVIER LEACH: *What is reason?*

JAVIER LEACH asked for Prof. Walach's comments on what had been discussed earlier related to the theme of the seminar: «What is reason?». Formerly when discussing mathematics, we needed to admit incompleteness. It is not enough to have one set of axioms; we need different sets as one is incomplete. There seems to be a similarity in the case of entanglement, because you need to interpret experience and one set of axioms isn't enough. The fact that you need two sets of axioms leads to the question: Are there two types of reasoning?

HARALD WALACH not only agreed with Prof. Leach, but also stated that it may be a way forward. Since the model is about incorporating different viewpoints, as this is what complementarity means, the finding that you actually need two sets of axioms in the formalization is precisely what the model is doing. The interesting thing is that if this is done you establish the formal requirement for non-local correlations within systems.

The moderator concluded by reminding the participants that during the debate session there would be time for further in-depth discussions.

## V. DEBATE WITH GREGOR NICKEL AND HARALD WALACH

Javier Monserrat, moderator of the debate, first presented a scheme summarizing his reflections in connection with the two presentations of the previous day (this scheme has been expanded in the two contributions of this professor that can be read below). Then he initiated the dialogue with the following question.

### JAVIER MONSERRAT: *The need for a formal system appropriate to describe the holistic world.*

JAVIER MONSERRAT asked whether we have the right formal system as an appropriate instrument to understand and describe the holistic world. Until now mathematics has described the world of differences. In the quantum mechanics, along the last century, the mathematical instruments that have been used are inspired in mechano-classical mathematics. We have applied these instruments to understand the holistic phenomena, but he wanted to ask: Do we have in mathematics possibilities to construct new instruments to understand this holistic world? He then mentioned that Walach had spoken the previous day about this necessity to explain the holistic world, related to the necessity to revise the classical quantum mechanics.

GREGOR NICKEL wanted first to slightly change the question, adding two words to it: Do we have 'the right' to use formal systems as an appropriate instrument to understand the holistic world? In his opinion the question is not to look for another formal system to describe the whole world of holistic features, but what happens if we use formal systems to describe the world. Because it is quite an influential tool to look at things, he said it is not sure whether we could see everything with that tool. If we rely on mathematics as a formal language, there are many special stories that get left out of the picture: psycho-social experiences, experiences of time... For instance, the Prado Museum houses the terrible Goya's picture of *Chronos*, the time: it is time, but a completely different time from the real line we use in physics. This is just one state after the other, the one we have to choose if we want to tell the story of evolution. This very concept changes the story that you can tell, if you formalize, for instance this character *Chronos* would disappear. In many situations it is just fine to do so, but if you want to pinpoint holistic world as a whole worldview then Nickel would be sceptical whether you can do it with formal sciences [35].

JAVIER MONSERRAT answered that formal sciences have been useful for scientists, physicists for example, because they provide many formal structures. The physicists need to understand the relations among many natural elements, and they can take from the formal sciences a formal structure, without any real content, that then can be used to organize the structural connections among all those elements. He then quoted Walach saying the previous day that if we do not have a model we cannot understand reality; Monserrat also stated that scientists have used formal sciences in this way to understand reality. The problem now, in his opinion, is that we have not an appropriate formal system to describe the world that we are now beginning to know, the world of holistic structures.

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[35] Two short additional remarks made by Gregor Nickel after reviewing this summary: 1. The 'wholistic' features, well understood in quantum mechanics, can quite successfullly be described by the mathematical (functional analytic) formalism. 2. As it was in the last centuries, mathematics *will* develop new approaches driven by the needs, e.g., of natural sciences.

He then mentioned an article he had written recently [36] about formal systems to be applied to this holistic understanding of the world. Probably topology could offer some possibilities. Concerning time, if we make use of the usual structure to understand it we will arrive to the same reductionistic point of view, we are precisely looking for new possibilities to change the understanding from the pure mechano-classical perspective.

HARALD WALACH, though admitting that he is not a formal mathematician, agreed that we need a different way of looking at holism. The idea of the generalized non-local correlation, introduced in his previous talk, might be perhaps at least a starting point. He also thinks that we will probably need complementarity of models. At the moment we are approaching everything from the vantage point of science, a colonializing model, and natural science being considered by itself the best and only approach. So everything has to go the way natural sciences have used to work, and we are naturally looking for a formal mathematical model. The solution might be not to go down that road, but to go for a complementary stand, even in methodology, maybe phenomenology is irreducible, it cannot be captured by science and by formal approach, because it is by nature individual and irreducible, something that cannot be reduced to general structures.

**JAVIER LEACH: *Structures and systems, are they the same thing or different things?***

JAVIER LEACH asked then for clarification about two terms being sometimes used indifferently: structures and systems. Are they used for the same thing or for different things?

JAVIER MONSERRAT said that speaking about structures is speaking about elements (as in set theory), operators or projectors (between the elements) and then the resulting unity. But we can also talk about dynamical structures; a system is normally a structure with a certain dynamical sense.

JAVIER LEACH replied that the term 'structure' is a basic concept used in formal theories, and of course, dynamic structures are also considered. But nowadays, it seems that people prefer to talk about 'systems', as a formal concept. There should be a reason for this preference. In his opinion, when we speak about 'systems', we do a meta-theory of 'structures', considering the relations between them, envisioning bigger and interrelated structures. The inherent dynamic sense points to a more open theory, more oriented to the 'structures' we find in the real experience of the world. In order to do this kind of meta-theory we speak about 'systems'; a system is also something more concrete, more applied in a meta-logical level, a second level. At this level we know about some structures and we have some open ideas, some dynamical ideas of how these are related among themselves. Speaking formally we need to distinguish between these two terms. With a classical model theory, everything is supposed to be explained with models, where a model is a structure. In Leach's opinion, it seems that when we have a model of models to interpret different realities is when we speak about theory of systems.

JAVIER MONSERRAT added that, for instance, the famous group of mathematicians in the beginning of the last century (N. Bourbaki) said that the essence of mathematics is the imagination of structures, but now it is usually said its essence is computation (A. Turing). As an example, we know by physics that a system of photons could be in a

[36] «Formal sciences: as an anthropic product of human reason», in: HELLER DEL RIEGO, CHRISTINE (Ed.), *God Seen by Science: Anthropic Evolution of the Universe*, Editions UP Comillas, Madrid, 2008, 325-337. Downloaded at: http://www.upcomillas.es/Sophiaiberia/doc/Conference%20book.pdf

corpuscular state, but in a certain moment these photons enter the so called quantum coherence and the vibration of each individual photon disappears. The result is a system of photons in a unitary vibration or wave function. So, how can we apply to this system the concept of structure (elements, projectors, and operators)? We need new possibilities to understand reality. In relation to a pattern of light (Gibson) outside the human retina we may speak about elements, but it is in resonance with an internal system of neurons and quantum phenomena that are taking place in the brain. To speak about these possibilities we need new formal sciences, to describe this holistic stage of reality, and then we could probably understand better the holistic reality.

**Miguel Lorente: *In order to understand reality we need more phenomenological intuition in connection with the real world, no more mathematics*.**

Miguel Lorente preferred to concentrate on the problem from the epistemological point of view. He pointed out that in the last century the philosophy of the so called logical positivism recognized only some mathematical level of knowledge. Therefore everything had to be reduced to mathematical laws and the coherence between these laws, the rest of it being considered by these philosophers as completely nonsense. That was a very bad step to understand reality, but it helped to stress the importance of mathematics, the structure of reality. Now we are talking of the need for some new idea of what reality is, as (expressed in Javier Monserrat's scheme's) number II. Ontology. This reality we are trying to understand cannot be explained from the pure mathematical scheme, we need a phenomenological level to understand what is behind this structure, what we call reality. And this is something that we understand not from the pure structural way of thinking but from the phenomenology of real sensations and intuitions of the real world. In his opinion in order to understand reality (following with the question posed at the beginning of this debate) we do need our structural mentality, but this would not be the most important thing for the new task; what we are lacking now is some kind of intuition connected to the real world. We do not need more formality and structure (we have a lot of this), but more intuition, more ontology that comes from our sensations and our contact with reality.

Harald Walach expressed agreement with Lorente's words.

Javier Monserrat replied that this is true, but the point is that we do not want to speak about the world from just these two complementary points of view. We do know that one thing is the phenomenological world and another thing is the physical, material, mechano-classical world of objects and bodies. But we are looking for a bridge between these two ways to understand the world. For instance Walach has presented 'entanglement' as a way to make a bridge between these complementary but irreducible perspectives. And that is the question. Many scientists now are looking for new ways to understand what the physical world is and, according to this new understanding of the world, to get also new possibilities to understand the physical support of consciousness and of this phenomenological experience we are talking about.

**Gregor Nickel: *Could we reverse the question, in order to break with the paradigm?***

Gregor Nickel proposed to just reverse the question [37]. Complementary to Monserrat's approach to look for a physical ground for perceptions and for reasoning, we could just

[37] Gregor Nickel added in his review: «In my opinion it would be an important step just to better *understand* the (natural scientific) paradigm».

look for the reasonable grounds of physics. For instance to ask for the framework used in the field of phenomenology or reason or whatever, there would be a broad range of philosophy to use for this.

JAVIER MONSERRAT suggested that the two points of view are probably complementary. He admitted that he had been speaking from a bottom-up point of view, to find physical support of phenomenological experiences, such as consciousness. But we can take the mind, or formal sciences, as departing point and look after an understanding of the physical world that could make possible what we are now experiencing (that is, human mind, formal sciences and so on). That would be a top-down way of reasoning.

GREGOR NICKEL pointed out that he preferred to say that it is an orthogonal way, so that not only one direction is involved. The ways of reasoning would be more like circles. Much depends on what ground you start with, if you just take the scientific picture for granted and then ask how reason evolved, how the mind and perceptions, etc. are structured, then you end with a completely different picture than if you start with the experience of being a mind having relations with others, a social context, etc., and then look for the scientific logic, to see how do we argue within science about phenomena.

JAVIER MONSERRAT replied that in his opinion we do not need to take for granted a scientific physical description of the world. This is always in progress; we are precisely looking for new ideas.

GREGOR NICKEL alluded then to the basic paradigm. New experiments look for repeatable situations, for patterns which you can reproduce. And then mental constructions are used to gather consistency etc. to describe this. This methodology has not changed so much. The physicists try to adapt to new phenomena and even try to look for new formal structures. Of course we should look for new mathematical structures. During the ongoing of time we will surely discover and invent new mathematics in order to be more precise and catch more phenomena in that way. But Nickel doubts this is really the basic question to understand the holistic world, since we are not breaking with the paradigm… Monserrat had said before that there is a complementarity, but if we are enforced to look at it in the scientific way, to express the ideas in the way of science, in Nickel's opinion we might lose much of the content we wanted to keep.

### HARALD WALACH: *The need to build bridges between the scientific and the phenomenological perspective.*

HARALD WALACH declared his agreement: if we have to reduce the phenomenological view to a scientific one, we do lose information, richness, content... This is why he thinks we probably need both types of approaches. He has used a scientific approach to transport the idea of holistic relationship within systems, as a bridge building exercise. He could have come from a completely phenomenological point of view, just describing phenomena (as Jung has done describing synchronicity) without using any scientific perspective whatsoever. But Walach has done it as a bridge-building exercise because it is important for science to look at holism, and to learn from the phenomenology of experiences. Coming from the phenomenologically point of view and trying to find a model within science, he could finally even use the terminology of science (such as 'non-local correlations'). So he admitted to having submitted to the colonializing influence of science, for the sake of bridge-building.

GREGOR NICKEL commented on the historical development of Walach's complementarity concept, the examples he used like grace and justice. Historically, the pioneers in quantum physics, especially Niels Bohr tried to find common sense examples in order for physicists to understand a strange phenomenon within physics. Then physicists became step by step used to this phenomenon, until it became a quite well understood and quite manageable concept in a technical sense. And now Walach uses this term complementarity, which is sort of a technical term within physics, to say there is more in the world than merely physics. All this makes a strange loop.

HARALD WALACH added that it's even stranger. The term 'complementarity' was originally taken from perceptional psychology, with its images, and this situation makes actually for a very interesting double loop.

JAVIER MONSERRAT said he completely agreed with those points of view. If we are speaking about a scientific holistic view of the world we do not intend to explain all the content, for example, of a human being. We cannot possibly explain emotions, biography, ideas, connections, things that we can only experience. Of course, we are not trying to reduce all human sciences (politics, sociology, arts...) to a reductionistic point of view. But in his opinion the problem today in sciences, in the universities, is that the majority of scientists still have a reductionistic point of view. [Harald Walach stated his agreement here]. For example in cognitive psychology, in America many psychologists ascribe to a computer interpretation of the human mind, that is, a robotic understanding of it. We need to understand the fundaments of this connection between matter and mind, this is precisely the connection about the holistic experience, and it would be the basic explanation of human beings. But of course the human sciences would be independent, would have their own field, without interference from the pure physical sciences. Monserrat also wanted to stress that sciences in their major part are pure theory. In particles physics the string-theory is pure speculation. Also when speaking of the empirical basis of science, we should not speak only about experiments, because there are many other possibilities of empirical evidence, and we should try new empirical methods for human sciences, although stressing the independence and legitimacy of the various theories to think about the world.

### SARA LUMBRERAS: *What are the basic categories of space and time?*

SARA LUMBRERAS spoke then in relation to whether the formal sciences we have now are appropriate to study or to grasp reality. She wanted to reflect about basic foundations of the natural sciences, such as space, time, and matter. Nickel had proposed a model for movement (in one of his papers sent previously for preparation to the seminar participants): a way of assigning to each instance of time, that would be part of a continuum, one point in space. But some people have questioned that sort of natural framework for space and time, for example Julian Barbour[38] says the only things that exist are space configurations, there being no such thing as time, and from that departure point he derives basic physics like the laws of Newton, then also relativity (still with no time, just configuration states), and lately he has been able to find something that is quite consistent with quantum mechanics. So, how certain should we be about the natural viewpoint for space-time, the basis for empirical sciences, is something to be comfortable with?

GREGOR NICKEL showed his curiosity about this case. He does not pretend our usual view is the canonical framework for science to formulate space-time for ever. But it is quite far reaching, covering much of the science since Newton and more or less it is the paradigm framework for most main-stream science. But of course if you use that framework,

[38] BARBOUR, JULIAN, *The end of Time*, 1999.

you rule out much… For instance, if you have a universe whose course is once and for all fixed from the outset you will never be surprised by the evolution of any system.

SARA LUMBRERAS replied that this theory she was talking about would not really be a complete determination. Although it is really very counter-intuitive, one should read it to be able to judge it. The basic thing would be to have a universe widely full of an immensity of possible states. The only thing that can be determined in it is a path (not an instant in time) that can bifurcate, producing a mix of probabilities.

GREGOR NICKEL pointed out that one of the main differences between a scientific approach and a philosophical, phenomenological or ethical point of view is the answer to the question about what brought freedom. If we think that there are no free decisions, in the sense that you have to take responsibility for what you are doing, then we have a completely different picture. This is quite similar to having once and for all fixed universes; in it you can forget that you are a player in the game, not just a part of it. You, as a scientist or theoretician, have to act and take responsibility for what you are doing. And then you try to look from the outside on the whole game, and try to reflect on it, what changes your status in that game, so you tend to invisibilize this role as an observer, as a theoretician. Gregor asked then Sara if the author she was talking about did describe himself making the model within this model.

SARA LUMBRERAS said he tries to and also does reflect about freedom. He says that what he does depends on the mix of probabilities, and the mix of his decisions is representative of his own nature. What he says is not that everything is fixed but that every possibility that is consistent is present in the entire universe.

GREGOR NICKEL asked why inconsistencies were left out.

SARA LUMBRERAS asked how any inconsistent possibility could exist. But she does not really know why this author leaves them out. He presents a study about movement and she just wanted to question the basic categories of space and time.

GREGOR NICKEL concluded that in his opinion the framework of mainstream natural sciences is not 'the' canonical framework. But in order to do science we need conditions for experience, and two of these methodological (esthetical) conditions are time and space. Without them we would not have experience in the proper sense, but to formalize this quite influential step is another question. He then added that these are not the last words, that there could be special situations or special phenomena to deal with differently and of course, we could find suggestions and proposals for these special cases…

### JOSÉ LUIS SAN MIGUEL: *Thirst for qualitative aspects?*

JOSÉ LUIS SAN MIGUEL stated that formal thinking or mathematical thinking is purely quantitative and excludes qualitative aspects. This problem was pointed out two centuries ago, since formal thinking began to give structure without qualia. Probably Pythagoras included it in the beginning, but modern mathematics has left it behind.

Another example is the Jungian theories that were specifically expressed in a qualitative fashion and were successful at reaching the population, although it was separated from the mainstream development of psychology as it was not seen as scientific.

In his opinion, the exclusion of the qualitative is serious as it excludes values and sense that are lacking in society. Is it possible that current mathematics could be qualitative?

GREGOR NICKEL recalled that Aristotle founded mathematics primarily at the quantitative level (equal or not equal) but also included quality such as the shape of a pentagon or a hexagon are qualities as they have different shapes. Also to be straight or bent are geometric aspects that were discussed in the course of mathematics. Yet a more modern mathematics such as the Bourbaki School – which is already old – employed only structure without pictures, nor qualities nor intuition. But this is only one – quite strong – aspect of mathematics. One should not underestimate the inner discourse of mathematicians who often employ a qualitative discourse such as this *theorem is deep* or *this one is dull* when solving interesting and profound questions of analysis.

HARALD WALACH added that this is right with regard to psychology and partially right with regard to the whole pace of science. The Scholastics believed that «quantity and quality do not convert into each other». This is a deep rooted belief within science and through the dominance of the natural scientific approach which uses mathematical formalisation, so, many qualities were set aside.

Jung is a very good example as he refused the mathematical approach and remained qualitative throughout his career, which is why he was not integrated and disregarded as not being scientific. His personal view is that we need both approaches and in psychology this might occur.

JAVIER MONSERRAT pointed out that today in a computational understanding of mathematics, for example robotics, we can talk about simulation of qualitative aspects of human mind such as emotions. A robot will not have emotions but these can be simulated and in this sense inside of the mathematical world we can simulate qualitative states of reality.

JOSÉ LUIS SAN MIGUEL replicated that the simulation is not reality.

JAVIER MONSERRAT stated that the ontology of a robot and of a human mind is obviously not the same.

HARALD WALACH added that the robot doesn't simulate emotions but the expression of emotions, which is an important difference.

JAVIER MONSERRAT agreed and concluded that the robot still has the computational or algorithmic possibility to evaluate the stimulus from the outside world and simulate emotions.

### JAVIER MONTERO: *What is reality?*

JAVIER MONTERO began by asking what reality is. We all assume that reality is well defined, but this is not certain. One is not able to distinguish between reality and a good simulation.

Returning to the earlier discussion about the position between reality and formal mathematics – up/down, orthogonal – he added that we can't talk about reality without a knowledge structure. It is not that they are orthogonal, but that reality can't be perceived without a knowledge system.

One of the problems that most empirical scientists have is that they believe that they do not need a knowledge system for their research and that there experiments do not use any logic at all. But this is false as it depends very much on the logic that is used to design the experiment.

Even in the debate we have seen how there are different logics, referring to the inconsistent possibilities that could arise and how this is not logical. Real life is neither consistent, nor logical.

JAVIER MONSERRAT agreed that we do not know what reality is and that this is the quest of human reason and philosophy. Until now we have maintained a reductionist point of view in science and we are now looking for a holistic point of view, but it is being discussed and is still an open question.

JAVIER MONTERO clarified that what he meant was that you can't talk about reality without using a knowledge system. What should be done is to use different logic and structures abandoning the binary logic and another world could be found. We are all children of Aristotelian logic and we design experiments to be consistent with this logic, which is a mistake. We refer to things that happen or do not happen or if they are consistent or inconsistent. But many phenomena do not follow these rules and can't be seen using them.

JAVIER MONSERRAT gives the example of quantum mechanics.

JAVIER MONTERO replies that as far as he knows quantum mechanics uses probability that is based on Aristotelian logic (binary logic).

HARALD WALACH says that he welcomes this comment very much and is what he tried to convey during his presentation yesterday.

**CHRISTINE HELLER:** ***The importance of natural language in establishing knowledge systems.***

CHRISTINE HELLER commented that if we accept that the structure of knowledge or epistemology – instead of Poli's emphasis on ontology – it seems that they can be rather limiting to what reality is. Considering the theme of the seminar, when we consider human reasoning, it mainly uses natural language in all models, such as what Nickel mentioned earlier about the qualitative terms of depth or dull describing a mathematical theorem or the fact that formal language does not contain irony or contradictions. Natural language is a very important aspect in constructing mental models and what is the possibility that the metalanguage of natural language be knowledge?

GREGOR NICKEL agreed that you can't escape from language and that it is indeed used to transfer constructions, feelings and knowledge, whatever you might call this.

HARALD WALACH said she had a case in point there, but there is experience that can't be expressed in a binary system – so you say something and it is clear – and that is why there is poetry and art and good philosophers attempt to use language to capture the depth of experience. It is dangerous to reduce experience to language, not that you are implying this. It is an important point of view, but there is more to it as there is experience beyond language.

CHRISTINE HELLER agreed and continued that it is language as a tool for constructing mental models in the same manner that mathematics is a tool for constructing simulation models. It is this analogy that leads her to consider that perhaps language is getting in the way of perceiving and describing a more holistic model. There seems to be some limiting aspects of natural language as well as of formal languages.

HARALD WALACH said that it is a dangerous tendency to reduce or equate mentality with propositional structures, whether it is formal or natural language.

JAVIER MONSERRAT indicated that in the orthodox epistemology of science there is a fundamental principle or theorem that to construct a scientific language object (*lenguaje objeto*), another language is needed every time and this is called the metalanguage, that is normally the natural language. Our minds and the structure of our reason is that of the natural reason and are related to its emergence. This emergence is based on this experience of the world that is quantum, holistic experience and also a mechanoclassic experience of the world. In our mind we have much more elements than in science as we have a holistic experience and this is what science is trying to reach. But he acknowledges the comment and says that the content of natural language is indeed very important and is needed for science.

JAVIER LEACH commented about natural and formal mathematical languages. The existence of natural language prior to formal language can be proved by explaining mathematics in any natural language. Mathematics extracts the basic objective structure of natural language, as this structure is common to all natural languages. It is the natural language that structures reality and how we access it. So, in formal languages there is a sort of violence towards natural language as we reduce it in order to communicate and have clear ideas, but possibly we also lose contact with reality.

JOSÉ LUIS SAN MIGUEL continued with the debate by referring to the historical case of quantum physics and that the quantum physicists' attempt to use only formal language to describe the phenomenon they analyse. He pointed to the bifurcation between them and specialists in scientific communication (divulgation) who are often accused of lack of rigueur, because they frequently find similes and parallelisms to describe science to the general public. It is interesting as a current sociological case of division between scientists that use natural language and those that are considered as *serious* are those that employ formal language.

**CHRISTINE HELLER: *Could there be a signal that has not yet been detected in non-local correlation?***

HARALD WALACH agreed that there may be one that has yet to be discovered, as they have not looked for it. If he was to choose another model it would be that of Rupert Scheldrake's morphogenetic fields. He is postulating that there are immaterial fields that influence somehow – the somehow still needs to be clarified – material reality. You could also envisage other type of signals, but you have to be aware that you'd have to shift the whole framework.

CHRISTINE HELLER added that they are looking for a unified field, so it wouldn't be so strange that another type of field could exist.

HARALD WALACH said that there would be a major shakeup and it is easier to use the physical framework that exists and extrapolate it to other kinds of systems. To postulate a new form of energy or field is a difficult endeavour that would encounter stronger opposition than that encountered with their model.

JAVIER MONSERRAT introduced the interesting new theory of mirror neurons, to understand the connection between the brain and the outside world. Now it is known that if a person is looking at another one who is experimenting pain expressed on his face then, the first one will reproduce this holistic connection with the outside. There is coordination between the brain and the structure of another brain. There is a lot of research being done as it is an important discovery of neuroscience.

HARALD WALACH added an empirical point to the question. If you study those phenomena which are positively due to signals, you always find a signature in the empirical data which is contrary to what is expected by signals. This is because the data always show that sometimes you have an effect, sometimes you don't or an inconsistency in the effect observed – which is true for studies on morphogenetic fields or parapsychology – so that whenever you create a supposed signal you never catch the signal and this is why he believes that it is not a signal.

**JAVIER MONSERRAT: *Generalised model of complementarity to understand the emergence of reason.***

JAVIER MONSERRAT asked Prof. Walach to connect his point of view and general model of complementarity to explain the emergence of natural reason.

HARALD WALACH responded with a provocative answer by stating that the type of reason that we are using is only a limited type and that there is a reason to assume that there is a different type, for example, the concept of integral consciousness or reasoning of Jean Gebser. We are all tied down to a type of reasoning done in an individual head. In other cultures, and possibly different states of consciousness, maybe reason is reaching over and above the individual. Perhaps we tap at times to a generic type of reason and the model proposed would allow for a transcendence of individual reason towards something similar to an integral reason.

JAVIER MONSERRAT agreed that we don't have a closed understanding of reason and that we are searching for new possibilities that Walach's model has opened.

CHRISTINE HELLER asked as an autodidactic Jungian, if this integral consciousness was equivalent to the *Collective Unconscious* defined by C.G. Jung.

HARALD WALACH replied that you can use the Jungian framework to understand it, but he would frame it differently.

Moderator Javier Monserrat ended the session by inviting the participants to contribute to the seminar and to continue the debate with the invited professors over dinner.

## VI. CONTRIBUTIONS

### 1. **JAVIER MONSERRAT:** ***The evolutive origin of mathematics/formal sciences (contribution to Nickel's presentation)***

On the one hand it is a phenomenological fact how mathematics is being produced in the human mind. Mathematics has described its own activity by reflection and builds a self-understanding of its functional nature. This is a relevant aspect of the epistemology of mathematics (and of formal sciences). From this perspective, mathematics appears as a free creation of the human mind that does not seem subject to the strict determinism of the natural world, such as Nickel argued in his presentation.

On the other hand, within the general objectives of science, all natural fact (here the fact that the human mind has produced mathematics) must have an explanation. There must be a «system of causes» that has produced the phenomenon that is to be explained. Doing science means trying to know these reasons. It is very difficult to deny that these causes are natural (in one form or another) and therefore it is also very difficult to deny that there should be a «naturalistic» explanation of mathematics (formal sciences). There may be, however, many forms of naturalistic explanations and that is what we need to discuss, as I have pointed out in the dialogue with Nickel.

In this contribution I give my personal view on an issue that I consider essential in the epistemology of mathematics and of formal sciences: the natural causes which have led to the evolutionary emergence of mathematical activity and the formal reason in general. My opinion is only an explanatory hypothesis. I argue in this way only because it has in its favour a broad theoretical and empirical basis.

1) The general expectation of reason (and of science) is that all that has been produced within the universe has a «natural» explanation. What does «natural» mean? It means that its causes have been produced within the evolutionary dynamics of nature (*physis*): In other words, the ontology of nature is sufficient cause of the phenomenon that is to be explained. But throughout the history of philosophy two forms of natural explanation of reason (and of mathematical reason) have appeared: the evolutionary or *a posteriori* explanation (animal and human minds are formed by adaptation to a structural world by *a posteriori* sensations) and an *a priori*, transcendental, or let us say Kantian explanation (reason is produced by *aprioristic* principles, absolutely independent of experience, that being universal and necessary are the basis for the universality and necessity of science).

2) Plato has proposed an *aprioristic* classical way to understand mathematics by the intuition of the «essences» of a transcendent world. Plato has always had followers (the «eternal objects» of Whitehead and more recently Roger Penrose). But Plato explains our world (the sensitive world) by another transcendent world (the World of Being) and this explanation is very strange to science. Kant, however, explains reason by a structure of *aprioristic* and transcendental «natural» principles. But his explanation needs to isolate these early principles from sensitive experience to justify its universality and necessity, the basis of necessity and universality of science (and of mathematics), according to the rationalist philosophy against empirism (18th century). The Kantian approach is not currently compatible with the results of science which have moved to an evolutionary *a posteriori* paradigm. As Konrad Lorenz said, what is *a priori* in relation to an individual of the species is not *a priori* related to the history of the species as a whole.

3) Therefore, how to construct an evolutionary explanation of mathematical reason? We consider that, in principle, there is a difference between natural reason (the theme of our conference) and mathematical (or formal) reason. No doubt the explanation of mathematical reason depends on the explanation of natural reason. I think that in discussing the ideas of Roberto Poli a hypothesis has been formulated that is valid (as a basic principle) to explain both natural reason and mathematical reason. This hypothesis can be found in the summary of the first session (R. Poli): as an empirical fact the real world, to which living organisms must adapt to survive, is made as a system (structure) and therefore, life has produced evolutionarily a variety of forms of analysis, synthesis and representation of systems (structures) that can be detected from primitive organisms to the upper level of human mind. Human reason could well be understood as a higher form of systems (structures) analysis and synthesis (see session I: *Evolution and Anticipation*).

4) Natural reason in ordinary life is already systemic (structural). But so was the mathematical reason born in ancient societies. Mathematical reason appears then as a practical life necessity for structural analysis of space and time. Already in antiquity this practical analysis led to some abstractions such

as the Euclidean geometry. But both geometry and arithmetic (even in the abstract and axiomatic systems) were always referred to the structural analysis of phenomenological and macroscopic space-time. In a more clear form: both mathematical analysis and classical geometry, until the twentieth century, have been a structural description of a world of sets of objects, metrical distances and moments of time (temporal sequences). Mathematics described a phenomenal and macroscopic world of differentiated objects and deterministic causality. It described the space-time of our sense experience in a macroscopic mechano-classical world (Newtonian). But when science began to discover a microphysic world that did not meet the Newtonian principles (the quantum world), then it needed a formal system (mathematical) to describe that new world. Science, however, suffered major constraints and was limited because then it only had at its disposal a mathematical system developed for describing only a macroscopic classical world (not a new quantum world). Then our knowledge of reality was «forced» by the existent formal systems (designed only for a classic world). It is therefore understandable the doubts raised by Nickel in his presentation about whether or not the real world is written in the language of mathematics (that is in the mathematical language of a mechano-classical or Newtonian world).

5) In the ancient mathematics there were abstract mathematical systems, such as in my view, the geometry of Euclid. But they always wanted to abstract the structure of the real macroscopic space (phenomenological). Much later, in the twentieth century, mathematicians realized that their subject was free in front of the objective space-time (mechano-classical). Mathematics had served for centuries to describe it. But mathematics was the discipline whose aim was to construct free imagined formal systems, regardless of whether they represented or not the world of real objective space-time. Nickel has insisted on creative freedom to construct the mathematical formal systems that operate by their own logic. The epistemological maturity of mathematics ripened the first outbreak in the nineteenth century, but developed during the discussion led by Hilbert throughout the first half of the twentieth century on the foundation of mathematical discourse. Accepting that, in fact, mathematics is a creation of the free formal mathematical reason there is still an outstanding question: why natural reason has been able to produce the creative freedom of mathematical reason. That is, what are the natural causes (i.e., the «naturalistic» explanation) that can explain why reason has been able to imagine new «formal» worlds regardless of the objective mechano-classical space-time.

6) I think we can provide some consistent assumptions about the causes of the evolutive emergence of the «freedom of the mathematical mind». A) On the one hand, natural reason is systemic (structural). The traditional mathematical reason has also been as a fact a systemic analysis of space-time in geometry and arithmetics. It is therefore possible to assume that this «systemic habit» of reason has qualified mathematical reason to construct «imaginary structures» and «abstract formal systems». The transition from the concrete to the abstract is a natural process of the mind that has been described by epistemology in various

fields. B) Furthermore, according to the feelings of Walach, the actual experience is not only experience of a classical mechanical world, but also experience of entanglement in a quantum mechanical and holistic world. This holistic experience probably empowers natural and mathematical reason to understand that the macroscopic classical world does not exhaust all of reality. There could be types of reality that are not correctly described by classical mathematics and are needed to be described by new formal systems. This way mathematical reason would be impelled to find and intuitively create and imagine new systems, structures and forms of reality. Consequently, both the systemic experience of a classical space-time and the experience of a holistic reality (this complementary experience pointed out by Walach) would open the human mind towards a horizon of creativity, imagination and freedom.

7) One last observation. Nicholas of Cusa is one of the authors (particularly valued by Nickel) who have understood that the world consists of real opponents and differences, not a harmonious world. Cusa in his philosophy posits the existence of a real ontological dimension in which the final dissolution of the opposites takes place, i.e. the «coincidentia oppositorum» on a background of universal holistic unity. God is for Cusa the holistic final unity of all reality. It is my understanding that Cusa felt that the existing mathematics of his time (geometry and arithmetic of a world of opposites and differences in space-time) did not describe the real holistic world, but seemed to point towards a world where differences disappear (the polyhedron which tends to disappear in the infinite uniform field of the sphere). Hopefully his intuitions compel us to imagine the new mathematics for a holistic reality.

[I recommend reading the Sophia Iberia's framework document: «Formal sciences: as an anthropic product of human reason», in: HELLER DEL RIEGO, CHRISTINE (Ed.), *God Seen by Science: Anthropic Evolution of the Universe*, Editions UP Comillas, Madrid, 2008, 325-337. This document can be downloaded from the website of Sophia-Iberia [39].]

## 2. **JAVIER MONSERRAT:** ***Complementarity and entanglement as causes of the emergence of reason (contribution to Wallach's presentation)***

I believe the basic idea expressed by Walach in his presentation is correct. Bohr's idea of complementarity in quantum mechanics (wave-corpuscle duality) can be generalized to the psychological experience: we are open to an experience of two complementary dimensions, but phenomenologically irreducible. They are experience a) of an objective physical world which responds to the characteristics of determination and differentiation of entities (mechano-classical) and b) of a psychological world through which we are installed in the feeling of a holistic experience of unitary fields of reality.

Although these two dimensions are phenomenologically irreducible, they are also complementary. We cherish the idea that they are not contradictory, but they meet the unitary properties of the matter's ontology and therefore of the

[39] http://www.upcomillas.es/Sophiaiberia/doc/Conference%20book.pdf

universe (properties still largely unknown). The property of quantum entanglement could be a viable hypothesis to understand the physical world (quantum world); it has properties that might provide the basis to explain our phenomenological experience. Explanation based on the unitary ontology of physical reality. Our life is indeed an experience of entanglement present in all manifestations of mental activity in daily life of living beings (not just of human beings).

The consequence for the theme of our seminar seems clear: the evolutionary process that led to the emergence of reason had to be not only influenced by the experience of a mechano-classical space-time, but also by the experience of a holistic immersion in «fields of reality» that would contain the psychological feeling of a «realized entanglement». The big question that remains, therefore, raised (to extend the consequences of Walach's ideas to the explanation of the evolutionary origin of reason) could be enounced this way: What causal role in the production of natural reason did the two mentioned dimensions of reality have? In this contribution to the presentation of Harald Walach I want to propose an introductory outline of some ideas regarding this question that, in my opinion, we are not yet in a position to respond to in a definitive theory.

## I. Phenomenology

1) The phenomenological experience of humans (and also within their own level of animals) includes two dimensions. A) First, the *dimension 1* consists of the objective experience of the macroscopic physical space-time: a world of independent entities and separate objects, placed at a distance in space and evolving according to the measure of moments in time. This metric world, in space and in time, has been perceived as a differentiated chain of events produced by a rigid causal determinism. B) In addition, a *dimension 2* consists of the psychological and social experiences (self-experience of the psyche in its individual and social aspects). It is the experience that different entities come together in «fields of reality» and that physical determinism is broken by undeterminism, freedom and open creativity both in the animal and the human world.

2) *Dimension 1* can be identified with Popper's *world 1*. But the *dimension 2* would include both Popper's *world 2* (animal and human consciousness) and the *world 3* (the creative products of human mind). These two dimensions of experience are occurring in the phenomenological unity of the «psychic subject». But both are irreducible, and it is because both concepts (identification / indeterminacy, differentiation / unit area, etc.) and methods (quantitative / qualitative) used to describe them are irreducible. This irreducibility, in the phenomenological fact, does not deny the premise of an ultimate ontological unity of reality. This is a dual «complementarity».

3) Nickel's considerations are also significant in this perspective. Mathematics is a free creation that belongs to Popper's *world 3* (to *Dimension 2*). Self-reflection done by mathematicians as their own rational activity makes them understand that they are in a free and creative world that is beyond the

pure deterministic world of mechano-classical physics. The world of mathematics is then complementary, but irreducible to a certain way of understanding physical science.

## II. Ontology

We refer to the ontology of reality as seen by science.

4) Science is built on a monist premise or expectation. It is to postulate that everything has been produced by the evolution of a substrate which is the primordial deep ontology of the universe. This substrate is called «matter», but ultimately we do not yet know what it really is. Science considers what has been produced by the evolution of matter in the universe. It has deduced that after the *Big Bang* two dimensions of physical reality have been produced: They are, at present, irreducible both by concepts used for describing these two dimensions and by the methods used to do so.

5) The *dimension 1 of physics is the classical world*. It has been constructed to describe the dimension 1 of our phenomenological experience. It has studied the properties and interactions of objects in the macroscopic world. It is a world of differentiated entities and objects that interact by deterministic causal chains, as described by classical mechanics (Newtonian). Today we know that these «classical objects» have been formed by a certain organization of a type of matter (produced after the *Big Bang*) called fermionic. Its wave function makes it difficult (although not impossible) that these particles lose their individuality. Because of the fermionic matter, individual atoms with electrons (differentiated), all materials, physical bodies and living organisms (with a single, stable and differentiated body) appear evolutionarily. The properties and interactions of these bodies are described in classical mechanics. Its laws are extended to the explanation of the macrocosmos by the theory of relativity. In the macroscopic classical world the laws of the microphysics quantum world are not valid.

6) The *dimension 2 of physics is the quantum world*. In this dimension, physics has known more precisely what the microphysical world is, i.e. what are the primordial properties of matter (not of the matter evolved into fermions and organized in macroscopic systems or structures). All particles belong to quantum mechanics: Also protons and electrons (essential fermionic particles for the organization of macroscopic objects) have quantum properties. However, the classical macroscopic objects (Newtonian) do not have these properties. The type of matter in which it is more easily to perform all quantum properties is called, as we know, bosonic matter. Well, among others, the most striking properties of matter in accordance with quantum mechanics are four. A) Quantum coherence that explains the formation of a unitary field of undifferentiated matter. B) Quantum superposition explaining free openness to multiple and oscillating possible states. C) The quantum indeterminacy to explain freedom and spontaneity of the evolution of quantum states. D) The entanglement or EPR (Einstein, Podolski and Rosen) effects that explain the phenomena of action-at-a-distance or non-

local causality. In addition to these we should mention also the «complementarity principle» enunciated by Niels Bohr to take into account of the wave-corpuscle duality. These concepts are irreducible to classical mechanics: they can not apply to interactions between the classical macroscopic objects. In addition, methods for understanding, predicting and intervening microscopic events are not the quantum-classical macroscopic methods (quantum methods use the quantum Hilbert space theory and for predictions the statistical and probabilistic mathematics).

7) Matter always possesses the same quantum properties. But classical macroscopic objects as such do not have quantum properties and interactions (only mechano-classical). But the matter (individual particles) from which the classic world is made can have quantum properties and interactions (e.g. electrons). Thus, within a macroscopic classical view of the universe, quantum states are still being produced and they will continue the same way in the future. Therefore inside smaller objects, such as in physical objects or living organisms within the universe, it is also possible the existence of macroscopic quantum states (i.e. macroscopic quantum coherence).

## III. Life, generalized model of complementarity

8) Life has probably evolved from the physical reality as a combination of quantum and classical world. The former has been inserted (to find their own «niche») within the structure of classical macroscopic living objects. This quantum-classical unity has resulted in the emergence of life: that's why life has properties derived from classical world (a stable and deterministic body) and the quantum world (fields of holistic consciousness and freedom).

9) The Bohr's principle of complementarity was enunciated to interpret the wave-corpuscle duality. But we think it is right to extend this principle to interpret in general the quantum-classical duality given in the scientific knowledge of physical reality. In addition, we also think it is right to expand even further this same principle to the psychological world (as Walach rightly does, in our view). But in any case the principle of complementarity implies renouncing the monistic view of science and the expectation that all phenomena (classical and quantum) are explained from the same principles.

10) Walach suggested that this «explanatory unity» is perceived if we correlate the entanglement described in physics with the entanglement sensed by the self-psychological experience. I do agree with that. This quantum entanglement is very clear to us when we try to understand the field of vision as a «direct perception» in the sense of J. J. Gibson (can be viewed at: Javier Monserrat, *La percepción visual. La arquitectura del psiquismo desde el enfoque de la percepción visual*, Ed. Biblioteca Nueva, Madrid, 2008, second edition). It is also observed in the coordinated action of masses of thousands of fishes and birds and could be expressed in the neural activity of mirror neurons. It is less clear, however, if we apply the physical entanglement to explain the feeling of belonging to mankind,

or similar cases. We do not deny that there could be in these cases effects of entanglement, even if it only may be an assumption or expectation. But in these cases, superior cognitive factors should also be taken into account.

11) In any case, we believe that the pursuit of this «explanatory unity» should not be limited to entanglement. It should be also extended to the quantum coherence (which correlates with the «sensation of fields of reality»), the quantum superposition and undetermination (which correlate with the feeling of spontaneity and emotional freedom, i.e. the «choice» which was warned by the Von Neumann-Stapp hypothesis). Coherence, superposition, undetermination and entanglement are four properties intrinsically correlated that can not be separated. As a whole (and not only entanglement) they should support the general principle of complementarity, as has been proposed by Walach.

## IV. Reason

12) Walach's ideas, that we have just commented, lead us to establish a basic tenet of scientific epistemological nature: Reason had to be produced as a result of a perceived reality, given in living organisms, in accordance with this principle of complementarity. Living beings have developed representative processes to survive in a physical environment sensed in this complementary manner. They have felt both the reality of a classical world and of a quantum world. The poles, seemingly irreconcilable, of the duality present in this complementarity have produced in Western culture two irreducible types of rationality (reductionistic and holistic). In modern times, however, we have been looking for the «explanatory unity» of the two poles in a single rationality.

### 4.1) *Emergence of natural reason*

13) Natural knowledge of the phenomenological *dimension 1*. Sensory systems have allowed living organisms the formalization of a stable world of objects, differentiated in the objective structure of space-time. As indicated in my contribution to the Seminar's Session I, living organisms have developed processes (semiotic and signitive) of systems analysis and synthesis that have led to the higher hypercomplexity of human reason. Survival has required systemic representation of the objective space-time. There is a strong world, stable, determined, to be described and to be subjected to survive.

14) Natural knowledge of the phenomenological *dimension 2*. At the same time, natural reason has been based on the experience of a world open to the psychic experience of reality fields (sensation of body, the vision of light…) and the experience of self-creation empowerment. In primitive societies, it appears in the world of magic, noumenal dimensions, mistery and of strange communication with holistic dimensions... In the modern developed cultures it is the experience of the world of «spirit» as superior and distinct from the immediate world of objects. This feeling has been expressed in art and poetry.

15) In any case, natural reason has developed two types of rationality (the differentiated world and the holistic / psychological world). This dualism has been irreducible in immediate practice, but in the last term complementary. But natural reason has not been radically dualistic and it has always sensed the fundamental unity of nature.

4.2) *Emergence of scientific reason*

16) *Scientific knowledge of dimension 1: classical mechanics*. It is a fact that both mathematics and physics, began with the knowledge of the objective space-time. This was accessible by perception of the systemic structure of the macroscopic world through various sensory systems. Many centuries along this knowledge has resulted in the construction of classical mechanics. The physical world was considered as a system (structure), consistent with the systemic analysis that had been already developed by natural reason through evolution. The world of life was also studied as a system in accordance with the understanding of the physical world. In the first session of the seminar, following Poli's proposal (the idea of life from the perspective of systems theory), I believe we have followed mainly this understanding of mechano-classical roots of reason. This is valid and essential to understand reason that should not be forgotten, but then it is not the only one point of view (the same Poli said in his presentation, showing their distance from reductionism).

17) Radicalization, absolutization and universalization of the mechano-classical image of the physical world is what is known as reductionism. First it was inspired by the model of the machine in the eighteenth century (mechanistic reductionism). Second it was inspired by the model of the machine of our time, the computer (computational reductionism).

18) *Scientific knowledge of dimension 2: quantum mechanics*. When quantum mechanics was discovered (in the 1920's) the physicists knew that in physical reality there were strange physical phenomena which did not satisfy the laws of classical mechanics. Until the Bohr's atom (1915) electrons were understood as entities described in accordance with the classical Newtonian principles. But when it was understood that things did not go this way, the only available physical model was a systemic understanding of the classical world: classical concepts and formal systems that science had to adapt (and in some way «force») in order to mathematically describe and treat the new quantum world. For many years classical mechanics and quantum mechanics have been together, each one applied to the knowledge of their specific domains. This duality (quantum-classical), as previously stated, has been admitted in science as an extension of the principle of complementarity, conceived in advance by Bohr prior to the wave-corpuscle duality.

19) *In search of a «unitary explanation of dimensions 1 and 2*. Admitting the existence of an irreducible complementarity as a fact does not imply giving up the existence of an «unitary explanation» of the physical world. About forty years ago an intensive search of that «unitary explanation» began. In physics, scientists were

attempting to find a new conceptual framework through string theory (not the only alternative today, and besides more and more debatable). This new «unitary explanation» should overcome the irreducibility of the two complementary images of physical reality (classical / quantum). But it is not only this: today scientists are trying to link the two dimensions of physical reality (classical / quantum) with the two complementary dimensions of psychological experience (psychological / physical and mind / body), described by Walach. The physical / body dimension would relate to the classical world and the psychical / mental dimension would relate to the quantum world. Therefore, the classical / quantum «unitary explanation» would also facilitate a psycho / physical «unitary explanation» (the mind / body problem). In this way the new holistic physics that today is in its infancy would be born. I think we should accompany Walach (and others) in this way.

4.3) *Emergence of formal (mathematical) reason*

20) In my contribution to Nickel's presentation I stated my point of view related to the view that the existing formalizations are based on the classical macroscopic experience and probably they are not appropriate either for in-depth knowledge of the quantum world, nor to describe holistic aspects of the psychic world. I have explained an approach to these potential new formalizations in: Javier Monserrat, «Neural Networks and Quantum Neurology: Speculative Heuristic Towards the Architecture of Psychism», in José Mira (Ed.), *Bio-inspired Modelling of Cognitive Tasks*, Part I, Springer, Berlin 2007.

3. **SARA LUMBRERAS SANCHO**: ***Space and Time Ontology: new models for new physics.***

In one of professor Nickel's papers [NICKEL, 2006], he proposes a model for movement – and in general, for change – in which each instant in time (characterized as the set of real numbers) is assigned to one point in a state space. As much as this model seems to intuitively fit to our experience, it implies a number of assumptions about the nature of space and time that are interesting to explore. During the debate session I mentioned the timeless physics developed by Julian Barbour [BARBOUR, 1999] as an example of a different perspective. This paper reviews not only this concept but also other similarly provocative ideas that might prove useful for improving our understanding of the universe. Prior to this, the relevance of the philosophy of space and time will be briefly outlined and its history reviewed to provide some background for the discussed models. Finally, an approach where space and time are only defined by convention will be considered.

*The Riddle and a New Renaissance*

Space and time are such fundamental notions that they seem to resist any attempt to define them in a sensible manner (as in the celebrated quote from

St. Augustine, «What then is time? If no one asks me, I know. If I wish to explain it to one that asked, I do not know»). Their ultimate reality is beyond the scope of science yet the whole building of physics is based upon them. These concepts have evolved with science: absolute space and time were essential for the development of Newtonian mechanics; a space-time which depends on the observer and is conformed by matter was at the core of the revolution of General Relativity.

It is precisely General Relativity, together with Quantum Field Theory, what poses an intriguing riddle to science at the moment. Quantum Mechanics has already inspired non-local interpretations of the universe [Bohm, 1952]. Quantum gravity would accomplish the final step of a unification process started by Maxwell and his Electromagnetism laws. However, after decades of effort and many promising lines of research (such as string theory); such unified theory has not yet been found. It is in the mind of many that the next scientific revolution will come with a change of paradigm that will reconcile the two different theories with a new understanding of space and time.

As expressed in [Majid, 2008], «There are elements of some kind of new Renaissance centered on our understanding of space and time». It seems clear that Science is now in need of deep philosophical input and that it is indispensable to identify and challenge our latent assumptions. The old questions should be revisited with new eyes. What is the reality of space and time? Are they continuous or discrete? (This question might have a different answer for time and space respectively). Are they independent of consciousness? Is empty space or time without change possible? In what ways do they interact with matter? Can two things be at the same place at the same time? Philosophy has reflected on these issues for millennia: returning to its insights can provide a starting point for the current considerations.

### *Brief History of the Philosophy of Time and Space*

Not surprisingly, it is in Greece where we find the two first well-known examples of philosophers of time. Heraclitus defended that everything in reality is in a state of constant flux and change. On the contrary, for Parmenides change is an illusion as it is logically impossible. Parmenides' disciple Zeno formulated the paradoxes that made him famous, in which he tried to prove that movement was impossible because it was an addition of an infinity of sub movements. As naïve as paradoxes such as Achilles and the Tortoise might seem today (now that we understand the concept of limit), they clearly show that Zeno and Parmenides assumed continuity in space and time. This was actually the case for all well-known Greek natural philosophers, including Democritus (for whom only matter was quantized, but not the infinite space in which it moved). Only in relatively recent times have we seen proposals of discrete space time.

Plato proposed three different kinds of existence: that which comes to be (matter), that in which things come to be (this would be space), and that after which it comes to be (that would be the model, the form). So for him space actually existed but not in the same way as matter.

Aristotle stated that the existence of space is «held to be obvious from the fact of mutual replacement». He even proposed a definition: «The space occupied by an object is the innermost motionless boundary of what contains it». However, time does not have a real existence, as the past does not exist anymore and the future does not exist yet. Nonetheless he gave time a definition: «Time is number of change with respect to before and after». Interestingly, time exists only in relation to mind as «it is a kind of number, and only the soul can count.

Medieval theologians held that God does not exist in time but in eternity, understood as an existence without time rather than time without beginning or end. As stated by Boethius: «Eternity is the entire and perfect possession of endless life at a single instant». It is interesting to note that for medieval masters such as St. Augustine or Boethius this divine all-at-once eye did not pose a threat to free will. God's knowledge of the future is not equivalent to a humane knowledge of what is to come, as for Him every moment in history is the same. It is useful to keep these considerations in mind when examining timeless cosmologies such as Barbour's.

Kant interpreted space and time as a priori notions that are not abstracted from experience but rather frame it. In order to have any experience at all, it must be bounded by these forms.

Newton created precise descriptions of the concepts of motion, space and time. For him time flows in perfect uniformity completely undisturbed. Space is absolute, much like a limitless transparent container that stretches to infinity. He agreed that one could only observe relative motions, but nevertheless stated that the absolute movements could be deduced.

Leibniz opposed this view, defending a relative view of space where only relative distances and speeds had a real physical meaning. His correspondence with Newton's spokesman Clarke has been very much studied. The final argument in the discussions was an experiment where a bucket of water is set to rotate. The curvature that appears in the surface of the liquid does not respond to the relative movement of the water and the walls of the bucket but very clearly to its absolute rotation. The discussion was deemed to be closed in favour of Newton's view.

It was not until the $19^{th}$ century that Mach, brilliant scientist and deeply convinced empiricist, raised suspicions about the invisible notion of absolute space. He argued that the linear or angular momentum of an object exists as a consequence of its relative motion with respect to all the other objects in the universe. This is what Einstein called «Mach's principle». Inertia will be then necessarily a concept that involves the whole universe rather than just the studied object.

Einstein was inspired by Maxwell's laws (that determine the speed of light without specifying with respect to which reference) to postulate that it was the same for them all. Actually, all experiments trying to measure differences in the speed of light due to relative motions with respect to the ether (like Michelson Morley's experiment) had failed. From this starting point he derived a new paradigm where all the laws of Physics are the same independently of the observer. Space and time are completely intertwined in one spacetime, and they are not immutable any more but conformed by the matter they contain. It is their geometry what will define inertia now, as inertial reference frames will be the ones following geodesic paths in this new landscape.

Relativity has very probably been the deepest transformation in our understanding of space and time, and has pushed ahead our knowledge of Physics. Now the question is whether a further change in the interpretation of space and time can bring us the next revolution. Perhaps its seeds are already in one of the evocative models discussed below.

### *Barbour's Timeless Universe and other suggestive Paradigms*

In this section we will review some interesting perspectives which differ from the mainstream interpretation and which could potentially trigger the next scientific revolution. Barbour's idea of an eternal universe will be exposed, together with other provocative speculations by other renowned current scientists.

### *The End of Time*

Julian Barbour was admittedly fascinated by Mach: «It is utterly beyond our power to measure the changes of things by time. Quite the contrary, time is an abstraction, at which we arrive by means of the changes of things». He reflects that when we measure time we are actually measuring distance, using the length covered by the clock's hand to infer the time elapsed. Solar time is the distance the sun has moved in the sky. Sidereal time, the distance the stars have moved. Atomic time, the oscillations of a cesium atom. Actually, it is possible to build the simplest clock by analyzing the relative movements of just three bodies moving inertially. This inertial clock was firstly introduced by Neumann, and then developed by Tait. With three particles, one can assume one of them is at rest. We can use the second one as the hand of the clock, dividing in intervals the distance it covers. If we assume it moves with unit speed, it is immediate to deduct the speed of the third particle. Actually, it is enough to count with three snapshots of an inertial system to completely define it in these terms, and be able to calculate all the future and past relative positions of its components. It is important to note that these snapshots come alone, i.e. without any additional data specifying the moment when they were taken. The possibility of fully describing a (very simple) system without time inspired Barbour for his search of a model for a timeless universe.

He proposes that the ultimate arena for the universe is the space of all its possible configurations. As these configurations are eternal he gives this space the name of *Platonia*. All *Platonias* have a distinguished state of minimum size and complexity which he calls *Alpha*. There is however no *Omega* as there is no limitation to the size or complexity of what can exist. If we trace a curve in *Platonia* we will have a history for the universe. Again, there is no need for time;

as in Tait's construction, having the relative positions of the elements is enough to define a history (and nothing stops us from checking the relative position of the hand of our clock for each point in the curve).

We can define distances in *Platonia* as we wish and, using them, trace minimum length curves or geodesics across its landscape. Some definitions of distance are particularly interesting as Barbour seems to be able to derive from them histories that are consistent with Newton's Laws or, with a more sophisticated definition, even Relativity. Therefore it seems to be possible to reformulate mechanics as a whole in a timeless fashion.

However, our experience still speaks for the existence of time. Barbour tries to explain the origin of this persistent illusion. In *Platonia* all the possible configurations of the universe exist eternally. However, these configurations appear with different intensity. He describes a mist that concentrates around the best solutions for the equation of the universe, in a way that resembles the probabilities from Quantum Mechanics. The solutions that resonate best are the ones that seem to be the most internally consistent. This internal consistency manifests in creating what he defines as time capsules. A time capsule is any fixed pattern that creates or encodes the appearance of motion, change or history. Thus our impression of time and movement is just due to the tracks they leave, which are actually timeless, and to the memories of them in our consciousness which are indeed timeless patterns too.

He even speculates that the universe probably has a tendency to find more suitable those solutions which are more structured. This will make the universes containing consciousness the most appealing. This could explain the fact that the reality we observe is highly complex and structured and yet this is a statistically highly improbable state.

### *Non-commutative geometry, foams, fractals and holograms*

Barbour's is not the only timeless cosmology. In causal networks, as in Penrose and Sorkin's work, spacetime is described by a discrete set of events for which it is merely specified what elements causally precede others. Penrose reflected as well on the values that were given to angular momentum in Quantum Mechanics. «Why should we say an electron has spin up or down rather than left or right?» [Penrose, 1971] We only know that one electron can take two different values for its spin: ½ or-½. The directions of space are meaningless. When we build a structure of elementary particles, we can find its total angular momentum. If we move one electron from one structure to another, we can find the probability of the second structure increasing or decreasing its total angular momentum by ½. This probability is interpreted by Penrose as the cosine of the angle that the two structures form. If an electron which is contributing with a positive momentum has 100% probability of contributing with positive momentum when transferred, then the two structures are exactly parallel. If it always contributes with opposite sign then they would be antiparallel. Intermediate values of probability would give intermediate angles. These probabilities are discrete but as the structures become more complex they can take more values and in the limit they would give origin to a continuum of directions. Spin networks do not consider time, but Penrose generalized them to a four dimensional space-time in Twistor Theory. In this framework the basic units are rays of light, in that a photon exists simultaneously in all the points it crosses due to relativistic time dilation.

In all the models presented above it is assumed that the distance from point A to B is necessarily the same as the one from B to A. Non-commutative geometry tries to relax this condition and apply non-commutative algebra to space. Alain Connes, a French mathematician, works in exploring the possibilities of this conception of space [Connes, 2008]. In a way which is reminiscent of Democritus and his atoms with different shapes he even proposes that matter might be a manifestation of the deep structure of space-time.

It has been mentioned above that the assumption of continuous space-time can be the root of the Quantum Gravity problem. We know from Quantum Mechanics that distances below Planck's length are physically meaningless. Space-time could be based on a foam (as expressed by John Wheeler), where there would be some fuzziness at the fundamental scale. Physicists like Shahn Majid [Majid, 2008] study the consequences of such a description of reality. In particular, Majid's theory predicts that the speed of light would vary slightly with frequency. There are already experiments in place to detect these minimum variations in the light emitted by distant supernovae using the LISA telescope.

Tim Palmer proposed a new interpretation of Quantum Mechanics where the probabilities arise as a consequence of the intrinsic complexity of the structure of space [Palmer, 2009]. For him the deep reality should be described as a fractal. His main idea can be exemplified by the analogy of receiving the coordinates of a point on a very intricate coastline. Certainly we would not be able to know exactly whether the point belongs to the land or to the sea but rather a probability. Palmer holds that the probabilities we find in Quantum Mechanics are derived from a similar phenomenon.

It has also been proposed that all the information contained in the universe is encoded in its boundary. This ultimate hologram would encode in the two dimensional boundary surface the whole of the three-dimensional reality. If space is discrete, it would mean that for the surface to be able to store all the information, the inside should be much fuzzier. Craig Hogan from Fermilab believes this fuzziness can be behind the unexplained noise that is disrupting the GEO600 experiment in Hannover, designed to detect gravitational waves [Hogan, 2008].

### *An intriguing possibility*

According to Barbour, we can depict our reality without time and this as an evidence of time's illusory nature. However, even if this description was perfectly consistent with observation, it would not prove that time does not exist. It only proves that it is possible to mathematically produce physics without time, which is not quite the same thing. As we already do science using the concept of time, this would mean that we have two different possible models which might work equally well. Interestingly Quantum Field Theory has provided with another example where the two different theories formulated with different space-time backgrounds (AdS/CFT and T-duality) give equivalent results. Could it be the case that contradicting descriptions of space and time gave us equally good predictions?

Poincaré [POINCARÉ, 1905] highlighted the fact that our senses could not apprehend the geometry of space directly: geometric space, the true framework for our experiences, is different from the representative space which we infer from our senses. For a start, the experience of vision is a purely two dimensional phenomenon. However, we take the information from our retinas, our perceptions of touch and how these change with movement and combine them to form the three-dimensional representative space. As a result, «It is also just as impossible for us to represent to ourselves external objects in geometrical space, as it is impossible for a painter to paint on a flat surface objects with their three dimensions. Representative space is only an image of geometrical space, an image deformed by a kind of perspective, and we can only represent to ourselves objects by making them obey the laws of this perspective».

Poincaré proposes a mental experiment where we consider a world contained in a sphere where all the objects have the same linear coefficient of dilatation, so the length of any body is proportional to its absolute temperature. The temperature in this world decreases with the distance to the center with the formula R2 – r2, so in the boundary the temperature is absolute zero. Even though this universe would be finite, to their inhabitants it would be in fact infinite, as they would became smaller and smaller as they approach the boundary. These imaginary people would study the physics of such a world completely unaware of the thermal dilatations. When they move, they would experiment a contraction of their limbs in the direction of the boundary. However, this deformation would be considered a kind of perspective, and so their senses would adjust to correct it.

Poincaré points that «It would be a mistake to conclude from that that geometry is, even in part, an experimental science. If it were experimental, it would only be approximate and provisory. And what a rough approximation it would be! Geometry would be only the study of the movements of solid bodies; but, in reality, it is not concerned with natural solids: its object is certain ideal solids» He finally argues that experiment can guide us but it does not impose any choice of geometry neither can reveal what is the truest, the most appropriate geometry.

It is impossible to measure any distance without a measuring rod or without the possibility of moving the rod, as we can only compare distances when they are next to each other. We assume that the rod will remain the same in the process. These assumptions are the ones actually shaping the geometry that we find. We might find a different solution if we take another hypothesis. For instance, if instead of assuming that the rods are not distorted we assume that the speed of light is always the same we find relativistic geometry.

A conventionalist approach to space and time where their nature is only agreed by convention is plausible. It seems like we could get equally good theories based on very different assumptions. This might mean that their fundamental ontology does not exist independently of the experience that already assumes them, in a sort of unavoidable circularity. It could also be the case that it cannot be ultimately expressed mathematically, and we can only find different approximations to their true structure. Or finally, it could simply mean that their reality can be expressed with mathematics in more than one way. The different models that prove to work should be understood as descriptions of the same reality beyond their mathematical differences. The final aim of this paper is to motivate discussion on the latter possibility, with one single nature and multiple descriptions. A perspective on the history of the Philosophy of space and time, as well as some overview on the more recent developments as given above can be seen as pointing in that direction.

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## 4. **Miguel Lorente:** ***Contribution to Walach's presentation***

The presentation of Walach to the evolution of reason is based in an enlargement of Bohr's complementarity of the wave-particle nature of all material objects to the generalized complementarity of two aspects of a deterministic/differentiate structure of living organisms, together with the unitary fields description by the indeterministic/holystic reality that permeates all living organisms. We accept this view provided we make some philosophical reflections that are not contained in the scientific approach for the emergence of reason.

Our presentation is based in a very important philosophical school with the name «interpretationism» which is very closed to realism (see J. Gómez Caffarena, «Metafísica fundamental», ed. Revista de Occidente, Madrid, 1969). We develop this interpretationism in two steps. First, we follow the epistemological approach of the scientific knowledge analyzed by the modern philosophy of science of the material reality [see my article «Some Relational Theories on the Structure of Space-Time: Physics, Philosophy, Theology», *Pensamiento* 64 (2008) n. 242, pp. 665-691]. Second, we make a metaphysical interpretation of the nature of the material as well as of the conscious beings.

Finally, these two complementary descriptions of reality, that Walach tries to unify in one and the same reality, Monserrat has identified both descriptions of reality: on one side with the classical mechanics where everything is isolated and deterministic, and on the other side with the quantum aspects of microphysical reality (indeterminacy, coherence, superposition and entanglement). We follow the same scheme of Monserrat's presentation of some epistemological aspect as well as the ontological background, but we make some minor corrections to his model.

*The epistemological frame*

The first task we have to accomplish in the way to understand our model is to clarify the epistemological presuppositions in which we can fit the ontological aspects of reality we are trying to explain. We follow the directions of the modern philosophy of science without forgetting the metaphysical interpretation of our model. The result will be a combination of positivistic philosophy and a realistic one provided a synthesis of both can be achieved. In different places we have presented this scheme (see my contribution to the symposium «Discrete Integral Quantum Systems», march 2009, in Cambridge: www.newton.ac.uk/programmes/DIS/seminars/032616306.html), the principal points of it are the following:

1. Our knowledge can be considered out of three levels. 1) Physical magnitudes, such as distances, time intervals, masses, events, forces and so on, that are given by our sensations and perceptions. 2) Theoretical models, that are the generalization of metrical properties given by measurements and numerical relations among them. 3) Fundamental concepts, representing the ontological properties of the physical world given by our consciousness in an attempt to know the reality. We follow the directions of modern theoretical physics or chemistry, where the models are open to ontological levels as frontiers of reality.

There must be some connections between the three levels. Given a set of data from the phenomenological world belonging to the level 1 some theoretical model can be found in level 2 that correspond to those data. This is the theoretical background of the quantum mechanical rules of correspondence, namely, what is correct in the quantum level will be correct in the classical level, if we take the Planck constant going to zero, or, in more technical words, the wave packet moves like a classical particle whenever the expectation values of the wave particle gives a good representation of the classical variable (Ehrenfest's theorem). The level 3 is connected with the level 2 via the ontological interpretation we are going to make in the next paragraph.

These epistemological levels that are applied to the scientific knowledge can be considered as a particular approach to the theory of knowledge called «interpretationism» by which all the human knowing makes an interpretation of reality (see Gómez Caffarena, «Metafísica fundamental», above, pp. 423-436). This philosophical position requires that all the interpretations of reality can be applied to all aspects of beings, in particular, to all scientific objects. We are going to see that the three epistemological levels that we have presented can be identified with the three types of interpretations described by Gómez Caffarena: perceptual, scientific and metaphysical ones, that he defines as interpretation of the first, second and third degree respectively. We are going to summarise them and to compare with the three levels of knowledge.

1) Interpretation of the first degree or perceptual interpretation. It corresponds to the sensations and perceptions by which we construct the designations and denominations of external objects. We call them interpreted objects because they are constructed with the help of human constrains (like space-time, and so on). In this mechanism the apprehension of reality is visible through the caption of sensations and perceptions that take place in the first level of knowledge, where pure sensorial data are received in our senses through our sensation and perceptual mechanism.
2) Interpretation of the second degree or scientific interpretation. It consists on scientific/natural definitions, that are reconstructions of the perceived reality through anticipation of verifiable models. According to Kant the necessity of scientific definitions is based in the heuristic trust of the syntactic human language as carrying the semantic values in the anticipation of formal languages. The analogy of this definition with the epistemological level 2 in our exposition is obvious. Both refer to scientific models described by formal entities like formulas, graphs, geometrical figures which are presented with anticipation as hypothesis to be confirmed. A good example of it is the Rutherford model of the atom, in which the reality of the atom is restricted by the geometrical properties of the orbits.
3) Interpretation of third degree or metaphysical interpretation. We can describe it in two moments. The first one accepts the semantic reference of the syntactic formal system in a thetic way. In the second one the metaphysical interpretation will reconstruct the reality from an anticipation of formal systems that cannot be told for all models because they cannot be verified. We have only to our disposal the analogy of self-conscience. A confirmation can be achieved from a holistic global vision of all the results of all the sciences

*The ontological background*

After we have presented the epistemological levels of our knowledge about the systems that are present in the real world, we are going to describe this reality according to the same levels of knowledge.

1. The first interpretation of the reality of the physical world. In the first interpretation we consider only the data that are received by our sensations and perceptions (= internal sensations). These data can be explained in two aspects: position and motion for every particle or system of particles and the force that produces the motion. The philosophical entities that are involved in this model are the existence of an absolute space and time with respect to which the particle is moving and the efficient cause that produces the motion. Both motion and force are related by Newton's law (in a more sophisticated interpretation of the physical reality we can assume the relational theory of space and time, but we still have the force and the change of position or the change of relations of one particle with the rest of all the particles in the world). All these models belong to the classical mechanics as well as to the relativistic mechanics, although the acceptance of the theory of relativity avoids the reference to the concept of absolute space and time.

2. The second interpretation of the physical world corresponds to reality that is known according to the epistemological level 2) as mentioned before, where the physical reality corresponds to mathematical or formal systems that are constructed with the help of individual elements together with geometrical or mathematical formulas following the rules of theoretical models. According to J. Monserrat in his contribution to Walach's presentation the most striking properties of matter that can be found in the physics of quantum mechanics are: A) Quantum coherence. B) Quantum superposition. C) Quantum indeterminacy. D) Entanglement.

These properties of quantum systems can be derived from the postulates of quantum mechanics, which can be reduced to six, namely (see A. Galindo, P. Pascual, «Mecánica Cuántica» I, chapter 2, EUDEMA, Madrid, 1989):

*a)* Postulate of Hilbert space.
*b)* Postulate of quantum observables.
*c)* Postulates of measurements or collapse of the wave function.
*d)* Heisenberg indeterminacy relations.
*e)* Schrödinger equation.
*f)* Correspondence rules and equation of motion.

The coherent state (A) is a particular case of (d) where the form of the wave packet does not change in time and Heisenberg relations take the minimal value. The superposition principle (B) is a consequence of the Schrödinger equation (e) because this linear equation admits a sum of particular solutions. Quantum indeterminacy (C) is a consequence of the Heisenberg indeterminacy relations (d).

The entanglement (D) is a property of the collapse of the wave function (c). The control of the postulates of quantum mechanics is necessary in order to know whether all the principles of quantum mechanics are fulfilled; otherwise, we can derive some property of the model from some principle out of the quantum model.

All these properties of quantum postulates have a very important characteristic in common: the quantum systems are described by wave functions that represent some kind of indeterminacy, contrary to determinacy dominating classical mechanics. This indeterminacy of the wave function plays the role of some kind of a holistic structure different from the arithmetic sum of all the constituents. One reason to accept this interpretation is to think that, given two quantum systems with different wave functions, the indeterminacy is not given by the sum of two complex functions but by the absolute value square of the sum, or the probability density.

3. The third interpretation of the reality of the physical world: the metaphysical background. We take the most general and abstract concepts that have been proposed in the metaphysical tradition to describe and to analyze all the beings in the world. Using modern terminology (E. Coreth, «Methaphysik, eine methodische systematische Grundlegung», Innsbruck, Tyrolia Verlag 1964), every cosmic being has a double principle: the principle of immanent actions (the principle of being-in-himself) and the principle of transient actions (the principle of being in others). The existence of each cosmic being is realized by the mutual communication of the one being of higher perfection in other beings of lower perfection through the immanent principle (in two directions, actively and passively). The interaction of one cosmic being with others of the same perfection is fulfilled through the transient principle (also in two directions, actively and passively).

Two very important properties for all the beings in the Universe are the evolution and the unification of all cosmic beings (M. Lorente, «Karl Schmitz-Moormann une la teoría evolutiva con la teología de la creación»).

i) Evolution: the essential union between the one and the multiple as explained before is not static but dynamical: the one is self-realized in the multiple, increasing the interaction of the later with other entities of the same level, and the new structure increases the total perfection of the composite.
ii) Unification of all cosmic beings: the principle of being-in-self gives rise to consciousness and freedom in the most perfect (human) beings, but it can be found in the beings of lower perfection, like the animals and organic beings; these have an elementary conscience and an autonomy of action similar to the power of decision of human beings. Even in the organic beings one can talk of receiving and transferring information and some decision power that is confirmed by the more important conditions of the quantum mechanical systems: the probabilistic nature of interactions and the collapse of the wave function, corresponding to some kind of spontaneous decision (M. Lorente, «Una interpretación dualista de la probabilidad y del colapso en MQ», XXIX Reunión Bienal RSEF, Madrid, 2003, p. 794).

## VII. PRELIMINARY CONCLUSIONS OF SESSION II

When talking about reason there is a tendency to understand it only in terms of structures and systems analysis. There is no doubt that the real world is felt by living organisms as a system (as a macroscopic mechano-classical structure). Therefore, much of the functions of reason that aid the organism to adapt to the environment are made by means of structures and systems analysis (Poli, Session I). This can be seen from the ordinary knowledge of primitive societies through to the current period of scientific reason. But there are also certain manifestations of reason in the ordinary knowledge, the emotional reason, in language and in cultural life that do not respond to this pure analytical reasoning. We all live with the effect of a natural reason that continually breaks with the pure mechanistic-deterministic understanding of behaviour.

In this session of the seminar, by means of the contributions of Nickel and Walach, we have extended the framework of our reflections on the origin of reason. Nickel conveyed that mathematical reason is not subject to a reductionist world (classical) and to determination, but that it is creating its own worlds by way of free established conditions. Walach transmitted that consciousness is not only experience of a reductionist world, but of a holistic world that we perceive during the experience of entanglement. Thus the experience of reality can be understood according to a general principle of complementarity. Therefore, because of both the exercise of mathematical reason (Nickel) and the holistic experience (Walach) we are immersed in, we can conclude that reductionism does not contain all of the reality that we experience.

It is true that reason emerges from the experience of a reality that in fact is built as a system (structure). Therefore, reason is systems analysis in the ordinary knowledge and in science. But we must consider that the holistic experience (of entanglement) also imposes on human reason a way of understanding reality that demands new ways of feeling and of thinking that will successfully break with determinism. Hence, reason has been produced by a complementary experience of reality: discontinuous / deterministic reality (classical) and as «fields of reality» (holistic). The ordinary human during their life has got to harmonize their attention on these two rational expressions of reality. But the scientific reason has been built for centuries and centuries on the experiential basis of a reductionist world. Science seeks today to know reality relating to the holistic quantum world. But it is a path that is only at its beginnings.

The ideas debated in this session have opened some research areas. The first would be to study what is the trace left by ordinary natural reason of this complementary experience of reality (in the sense of Walach), followed by studying the trace left in both classical/deterministic and in holistic/non-deterministic reason. There is no doubt that in our ordinary lives we know that we live in a holistic reality and in accordance with that we exercise our natural reason. Moreover, this complementary experience has also left its mark on science. Science has come to discover the existence of a holistic world that it seeks to describe and explain. This fundamental issue has been mentioned in the discussions. Is the idea of system and structure useful for describing the classical reductionist world? Is it also appropriate to describe a world of «fields of holistic reality»? Is scientific reason «trapped» in the conceptual network of a purely classical world? These would be the problems that were discussed in relation to the «holistic» validity of the formal systems of science that are presently in use.

## VIII. ADDENDA OF SESSION II

### 1. Gregor Nickel's comments to the proceedings

*Professor Gregor Nickel raised doubts as to any «naturalistic» explanation of reason, on the claim that natural sciences are written in the language of mathematics and the consequent mathematical dependence of physics* [40].

— I think the crucial distinction between «nature» and natural science's picture of nature should be recognized; we find all too often a naive identification of these two. For example, there is no language in/of nature, it is natural science that talks *about* nature predominantly by mathematical language. Since «naturalism» claims to describe everything within the framework of natural sciences, it must use mathematics as a crucial tool of the description. This tool however, has to be investigated carefully.

*Does it make sense to think that mathematical reason is not part of nature?*

— To me it does not make any sense to 'think' about mathematics being some 'part' of 'nature'.

*Today there seems to be no reasonable alternative to the general evolutionary paradigm of science.*

— As every great metaphysical world view the «evolutionary picture» has its own descriptive power and fascination. It is, however, no clear cut concept of natural science (for instance, the course of the «world» cannot be arbitrarily often repeated, thus investigated by experiments).

*Mathematical reason expresses creative freedom, independent of physical objective reality.*

— It is not so clear, what «physical objective reality» might be.

[40] The correction has been implemented in the Summary, in order to better represent Nickel's position.

*Mathematics is a world created by the human mind that is not subject to a deterministic.*

— Determinism is a *methodological* principle of science, not an *ontological* principle of nature.

## 2. To Javier Monserrat's Contribution about Nickel's presentation

*On the other hand, within the general objectives of science, all natural fact (here the fact that the human mind has produced mathematics) must have an explanation. There must be a «system of causes» that has produced the phenomenon that is to be explained.*

— This, in fact, is the (fundamental) methodological principle of natural science; but why *should* we make a metaphysical principle out of it?

*The general expectation of reason (and of science) is that all that has been produced within the universe has a «natural» explanation. What does «natural» mean?*

— It is only a narrow part of reason, namely natural scientific reason, which seeks for explanations of the mentioned kind. Of course there is also a long lasting tradition of naturalistic philosophy (at least from Democritos and Lucretius on, to mention just two names), but there is also an equally long tradition of critique against that picture.
— What does then 'explanation' mean? What is the status of an 'explanation' emerging from a 'natural process'?

*Kant, however, explains reason by a structure of aprioristic and transcendental «natural» principles. But his explanation needs to isolate these early principles from sensitive experience to justify its universality and necessity, the basis of necessity and universality of science (and of mathematics), according to the rationalist philosophy against empirism (18$^{th}$ century). The Kantian approach is not currently compatible with the results of science which have moved to an evolutionary a posteriori paradigm.*

— Perhaps Kant's third critique could still bring some light into this field

*But when science began to discover a microphysic world that did not meet the Newtonian principles (the quantum world), then it needed a formal system (mathematical) to describe that new world.*

— The mathematical formalism (Hilbert spaces etc.) used in quantum theory was developed quite some time *before* physics discussed any quantum phenomena.

*Then our knowledge of reality was «forced» by the existent formal systems (designed only for a classic world). It is therefore understandable the doubts raised by Nickel in his presentation about whether or not the real world is written in the* *language of mathematics (that is in the mathematical language of a mechano-classical or Newtonian world).*

— The intimate connection between Newtonian physics and mathematics seems to me unjustified. Modern mathematics is very well capable to deal with the needs of, e.g., quantum theory, non-Newtonian space-time structures, biological systems theory (including feedback-systems) etc.

*Accepting that, in fact, mathematics is a creation of the free formal mathematical reason there is still an outstanding question: why natural reason has been able to produce the creative freedom of mathematical reason.*

— In a purely natural world that question «why» seems to me simply illposed.

*One last observation. Nicholas of Cusa is one of the authors (particularly valued by Nickel) who have understood that the world consists of real opponents and differences, not a harmonious world. Cusa in his philosophy posits the existence of a real ontological dimension in which the final dissolution of the opposites takes place, i.e. the «coincidentia oppositorum» on a background of universal holistic unity. God is for Cusa the holistic final unity of all reality.*

— This seems to be a misleading simplification. In the works of Cusanus, e.g., God is normally a *trinitarian* God. He is thus at least a *differentiated* unity (unity-equality-connection). Moreover, Cusanus invests enormous efforts to keep God and the World separated.

## 3. J. Monserrat's answers to G. Nickel's comments

Nickel's comments lead us to further deepen the analysis of the complex explanation of the origin of reason. During the Seminar it has been formulated the thesis that today, for science, there is a basic expectation: that reason has had a natural evolutionary origin. That is, it has been formed from a gradual evolutionary adaptation of organisms to the natural environment (we speak then of a 'naturalistic' explanation, and therefore *a posteriori*). Is there any alternative? If the mind does not emerge by evolutionary configuration of the mind, then what alternative is there? In the case that there is a certain alternative, what «system of causes» would then have produced reason? We do agree with Nickel's distinction between «nature» and «natural science's picture of nature», but the «naturalistic explanation» does not confuse the two. The reconstruction of a naturalistic origin of reason believes that living organisms have «sensed» and «perceived» (in higher animals) an «objective world» (including one's own body and self-sensitivity). Reason, in fact, has built a cognitive representation of the «objective world» (a «picture of nature»). To do so, reason is based on the experience of an «objective world» which is «sensed» and «perceived», but it is aware that its representation of the world is only a hypothesis that does not necessarily identify with the essential truth of the world.

The representation in the sense of modern epistemology (e.g Popper) is an open hypothesis, not a closed knowledge. However, reason has also produced a representation of itself in the scientific framework of a naturalistic explanation of the origin of reason. This explanation finds some assumptions. 1) That reason is the result of an adaptive process in order to achieve optimal survival. 2) That the way in which the «objective world» has been «sensed» and «perceived» has shaped the representative functions, logical and cognitive, of natural reason (a structural-systemic cosmos, life as a real system and a mind that works to represent through systems analysis / synthesis that «systemic objective world»: see Session I). 3) This sensed and perceived «objective world» (phenomenal) is not the «world in its essential truth»: reason must work to reach that essential truth through open hypotheses. 4) But reason, inspired by a «structural objective world», can imagine «formal systems»: the mathematical systems are part of those formal systems. 5) The rational representation of the «objective world» regards the ontology of the world itself as being systemic and structural (that's why the structural world's ontology has produced by evolutionary adaptation the logic and cognitive functions of natural reason). 6) The formal and mathematical systems, therefore, are not «part of the world», but an imaginative product of reason. 7) Notwithstanding, some of these formal and mathematical systems are useful for real sciences to describe partially some aspects of structural ontology of the world. 8) But some of these formal and mathematical systems are useful to describe in part some aspects of structural ontology of the world.

The scientific method is, by itself, neither deterministic nor indeterministic, nor purely experimental (also theoretical speculation): in addition, the structural ontology of the world known to science is also partly deterministic and partly indeterministic. For science (and also for the philosophical knowledge) is always inevitable to describe the facts (phenomena) and seek the explanation for their causes. Even for the scholastics God was understood as the *causa sui*. Causality is thus a principle of both science and philosophy (metaphysics). Is there any alternative? Has anyone postulated a metaphysical reality without cause? A real order without causes? Science seeks the causes as far as it can. But it accepts its limits and is open to questions, to be answered (if possible) in the context of philosophy and metaphysics. The naturalistic explanation of reason, as it has been discussed in the Seminar, should not be confused with «reductionist» visions of knowledge («reduced» to the pure scientist, as in some schools of positivism).

However, at its own level, within its own capabilities, science builds evolutionary explanations. It knows that the causes are earlier states produced in a previous evolutionary process: e.g. physical objects are explained from the *big bang* and reason (the psychic world) is explained from the evolutionary process of life. So the explanations emerge from a «natural process».

On the use of formal sciences in science it must be admitted that the formal structures (e.g. mathematics) are created before science has found its application to knowledge of reality. Part of mathematics (which existed before Newton) was applied to classical mechanics and a deterministic and mechanical image of the world appeared. Later, new empirical evidences and theoretical frameworks in physics led to the birth of quantum mechanics. Then, new mathematical instruments were demanded and, among other things, the Hilbert space was applied, which certainly existed before, as did the mathematics of waves (Schroedinger), matrix mechanics (Heisenberg) and Hamilton's equations (Dirac). But both classical mechanics and quantum mechanics led the formal imagination of reason to create new mathematical structures that helped to resolve specific problems of knowledge. It is therefore clear that mathematics has imagined many structures and systems that have not yet been implemented, either in classical mechanics or in quantum mechanics. All this is perfectly consistent with a naturalistic explanation of the origin of reason.

Finally, in my comment on Nicholas of Cusa there are no references to the Trinitarian aspect of God. Of course all Christians, as Cusa, admit the balance between trinitarian unity and the trinity of divine persons. But this trinitarian God is the ontological background in which the world and their differences have been created. So finally the «coincidentia oppositorum» postulated by Cusa in his philosophy shall happen, on a background of universal holistic unity. To say that, for Cusa, God is the final holistic unity of all reality does not imply a negation of the differences between God (creator and final ontology of all reality) and world (creation of difference within the divine ontology). To say that God and world (as the creator and the creature) are ontologically distinct does not mean they are «separate» (and still less if separation has to be understood as a metric distance in a mechano-classical Newtonian space).

Nickel's arguments seem to have a goal: to show that the hypothesis of a naturalistic (evolutionary) explanation was not consistent. In our view, it is consistent and the evolutionary paradigm is commonly accepted by science (and even current philosophy). It's not a perfect paradigm, but to replace it, it would be necessary to have a more consistent alternative. What could that be? We should explain what justifies our belief in a platonic world-of-being. Or perhaps explain why *a priori* transcendental principles (which have not emerged from the experience) do exist at all, where they come from and why they should have absolute universality and necessity, as Kant thinks.