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FUNDAMENTAL QUERIES

SUMMARY

In this chapter we shall allow ourselves to consider the basic questions of physics which are those bordering on metaphysics

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What is Truth?
Is the World Real?
Is the World just One?
Is the Universe Infinite ?
Does the Universe Expand?
Is Nature Governed by Laws?
Are Occurrences Predestined?
Is Gravitation Instantaneous?
Is Time Causally Dependent?
Does Time Involve Change?
Is Simultaneity Universal?
Is the World Contingent?
Is Nature Atemporal?
Does Time Flow?
What is Time?

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Q1. WHAT IS TRUTH?

The question of truth is one of the great problems of philosophy. There are three different views of how truth is established, viz. a) by *coherence*, b) by *correspondence*, c) by *consensus*. All three views are relevant with respect to *scientific truth* which is in focus of this discussion: a) scientific theories *must be internally consistent*, b) they *must correspond to empirical facts*, c) they *must be accepted by a community of professional experts*. However, it should be noticed that: a) internal consistency is no guarantee that a theory is built on sound premisses, b) incompatible theories may explain many of the same facts, c) even a large community can be mistaken. All these reservations are particularly pertinent with respect to Einsteinian relativity ...

Not all human expressions can be ascribed a *truth-value*, even not all verbal expressions. This shows the notion of *meaning* to be far more comprehensive than that of *truth*, whence the attempt to construe a theory of meaning from a theory of truth must itself be devoid of meaning. Verbal expressions that are carriers of truth-value we normally call *statements*, or propositions. Of truth-values we ordinarily reckon two: '*true*' (1), and '*false*' (0). Operating a Boolean algebra on the system of binary numbers we can compute the truth-value of a complex proposition from those of its constituents. This logical technique can be used in the construction of logical gates which can then be implemented electronically, with (1) for '*on*' and (0) for '*off*'. By such means we are able to construct a so-called *Turing machine*, i.e., a universal computer.

Using 'p', 'q', 'r' as symbols representing simple (un-analyzed) propositions, and following Tarski, we can define *the truth of* 'p' thus: "The proposition 'p' is true *iff* (i.e.: if, and only if) p". The standard *calculus of propositions* can then be constructed on the basis of various different sets of axioms, together with rules of derivation and definitions of *wff*'s (well formed formulas). A highly simple and beautiful axiomatics is that offered by Lukasiewicz in 1924, consisting of three axioms: *L.1* $(\neg p \Rightarrow p) \Rightarrow p$, read: "If not-$p$ implies p, then p" (if undeniable, 'p' is true); *L.2* $p \Rightarrow (\neg p \Rightarrow q)$, read: "If p, then not-p implies q" (thus contradiction involves absurdity); *L.3* $(p \Rightarrow q) \Rightarrow ((q \Rightarrow r) \Rightarrow (p \Rightarrow r))$, read: "If: if p then q, then: if q then r, then, if p then r" (i.e., transfer of truth-value by classical syllogism). If, instead of analyzing propositional syntax, we want to consider the internal structure of propositions, we must turn to predicate calculus or the theory of quantification, which was extensively made use of in ch.6.

The *calculus of predicates* is a modern development of the old *subject-predicate calculus*, due to Aristotle, which was found to be problematic on account of its metaphysical implications. The problem is that the subject apparently implies the necessity of referring to a thing, or entity, or substance; so the elimination of the logical subject, by way of reducing it to a description in terms of pure predicates, was meant to liberate logic from the fetters of Aristotelian ontology. For the same reason it is *very problematic to base a semantical theory on the assumption that symbols acquire a meaning by referring to things, or objects*, whatever their properties may be. Much more reasonable is it to assume that objects, as well as their properties, are constituted *by way of the actions we perform on them and the operational procedures we expose them to.* In the predicate calculus, *propositions* are construed by quantifying over *variables* representing unknown objects, of which we *affirm or deny* predicates representing properties; the *quantifiers* are *operators*, universal or particular, thus giving rise to universal or particular statements, resp. Natural laws are expressible by universal propositions, boundary conditions by particular ones. One of the great issues of contemporary science is whether this cleft can be bridged.

Q2. IS THE WORLD REAL?

What a silly question! Isn't the world simply a summary of what we consider to be real? Nevertheless, to answer the question isn't as easy as it seems. What do we mean by 'the world'? Is it the *sum total* of what we experience? - *now*, or in the *past*? And who are 'we', in the plural? How can we ever be sure that the world I experience is the same as the world you experience? Does anything at all remain *invariant* if the *perspective* is *shifted* from you to me, or me to you? It all seems so easy when we talk with people we know well and maybe even are very fond of, but if the identity of human persons surrounding us is put into jeopardy we are really in trouble. As long as the *communication between persons* is unperturbed we feel confident about reality, but surely, this is a very feeble foundation for a scientific conception of "the real world".

Personal perspectives on the world, when based on sense experience, are bound to differ. But we suppose that the *structure* of the real world is *invariant*, i.e. common to different people, and the task of natural science is precisely to disclose this structure describing it by a mapping. Even if we do not agree about all details in the scientific mapping of nature, we feel convinced that behind our sense impressions there must be a "real world" which causes what we perceive. This is what is meant by ***scientific realism***: a feeling of confidence, the belief in a "something" behind all appearances, without which the motivation to make science would probably vanish. This "something" Kant defined as "das Ding an sich" in contradistinction to "das Ding für uns". Did Kant leave us with any hope that science shall ever succeed in disclosing "the real thing"? Not at all! Not the faintest hope whatever! The hunt is like chasing a *fata morgana* in a desert. The same view is expressed by Rowlands [2007] p.60: "There is no such thing as 'reality' ".

So, what can we hope for? Well, *maybe we are able to map the structure of phenomena, i.e. of the world as it appears to us, indeed, as it must appear,* to observation and experiment. This is what Kant would tell us: whereas it is hopeless to obtain any knowledge of the universe as-it-is-in-itself, we can at least hope to get true knowledge of the universe as-it-appears-to-us; *the reason is that the universe of appearances is not independent of the way we comprehend it.* Just as our *perceptions* are necessarily encompassed by the framework of *time* and *space*, so our *conceptions* of what is, or happens, necessarily conform to *the way we think,* indeed *must* think. This Kantian view may be interpreted as stating a primordial version of the Anthropic Principle: "Der Verstand schöpft seine Gesetze nicht aus der Natur, sondern schreibt sie dieser vor"; and: "So ist der Verstand der Ursprung der allgemeinen Ordnung der Natur, indem er alle Erscheinungen unter seine eigne Gesetze fasst", [1783] §§36-38. A similar position was held much later, on very similar premisses, by Eddington: "My conclusion is that not only the laws of nature but the constants of nature can be deduced from epistemological considerations.", [1939] ch.4.

For my own part, *I would prefer to retain* ***truth*** *as a regulative idea in the sense of Kant, meaning that we should always strive for true knowledge of the real universe*, behind its various appearances, even though our universe is bound to remain an unknown, maybe unknowable, X. But this moderate stance *seems to face insuperable difficulties* if we consider the finite speed with which causal effects are propagated. The observable universe then presents itself to us as a sphere of concentric shells whose age is increasing outwards with their distance from the center. So, when looking outwards, we look into *the past*, seeing the universe in a temporal perspective. But how do we pass from ***world-view***, the world as it appears to us, to ***world-map***, the world as it is in itself, *now*, if *absolute simultaneity* is discarded in consequence of the finite speed of the propagation of light-signals? Without this, the very notion of a *world-map* seems pointless.

Q3. IS THE WORLD JUST ONE?

Apparently the real universe could have been many, and that in very many different ways. According to the many-worlds hypothesis of Everett and Wheeler, our world is not a universe in the proper sense of the word, but a "multiverse" consisting of an infinity of "parallel universes" co-existing "side by side", probably not in supertime, but in some timeless "super-spacetime". This "multiverse" is imagined to be *branching* "every second", or whenever something happens, the aim being to retain a *unitary description* of the entire "multiverse", represented by a unique quantum wave-function Ψ, without admitting a *collapse* of Ψ whenever an observation is made. In this way one pretends to have solved the ugly problem of "wave-function collapse".

In fact, something similar can be found in *modern tempo-modal logic* which has adopted the Leibnizian notion of "possible worlds" in order to make better sense of its semantic models. Just like the above mentioned many-worlds interpretation of quantum mechanics, tempo-modal logic assumes a *branching of possibilities*, or "worlds", *towards the future*, the present moment being the earliest branching point, and past moments connoting possibilities grasped or wasted. So the "multiverse", constituting an infinite ensemble of "possible worlds", can be visualized as a "tree of life", with "branches" pointing towards the future, its "trunk" being the actual course of past events, its "twigs" being the possible outcomes of present actions or accidental events, and each "possible world" being a linear course of future events leading forth from the present. Clearly, such "possible worlds", passing "zig-zag" from one branching point to the next one at various "angles" to each other, cannot be "parallel", but may rather be imagined as "bundles" of "world lines", or "future world courses", forking from the "trunk" at the "present present".

Now the question arises: Which status should be ascribed to this "multiverse", defined as the total ensemble of "possible worlds", or "temporal world lines"? Is it *reality*, or just *fiction*? It should here be noticed that *the many worlds interpretation* of quantum mechanics claims some wave function Ψ to determine the entire "multiverse" by comprising all possible events. The whole point of the hypothesis is that Ψ, albeit unknown, is taken to describe "everything"; hence it seems possible that we, at least "in principle", are in possession of a unitary description of the "multiverse" which enables us to comprise all possible futures in a single unified theory. Is it not legitimate, then, to say that the hypothetical wave function Ψ is at least "virtually real"? The same question turns up in relation to the "possible worlds" semantics of tempo-modal logic: are those "worlds" not, at least, "virtually real"? Here we are witnesses to a stark disagreement between *possibilists*, who are apt to answer 'yes', and *actualists*, who are disposed to say 'no'. However, if "Ockham's razor", the principle *entia non sunt multiplicanda praeter necessitatem*, is accepted, there can be no doubt about the true answer: ***Only One World*** can be real!

But there have been other attemps to profess the opinion that there are many universes. Thus it has been found incumbent to underpin the "big bang" idea by several *ad hoc* hypotheses. First the idea was hailed for lending support to the cosmological principle of cosmic uniformity. Next it was realized that the resulting isotropy and homogeneity probably was a little too strong, whence the observation of small ripples in the cosmic microwave background radiation was saluted for giving rise to the inhomogeneities supposed to be needed for the galaxies to form. Then, by a second thought, it was admitted that these inhomogeneities, after all, might grow up to prevent the uniform distribution of matter in space, so that a little more mixing was needed, whence the idea of cosmic "inflation" was put forth in order to solve this "mix-master" problem. In this way we got a "theory" describing the "multiverse" as an exploding "bubble-gum"!

Q4. IS THE UNIVERSE INFINITE?

In spite of such difficulties, scientific speculation has not been brought to a sobering halt. Cosmologists usually eschew *infinity* for the reason that it is not easily handled mathematically; but now the idea was seized upon in order to make sense of the so-called *Anthropic Principle*. According to this piece of wisdom, the universe is as it is, because we are its lucky inhabitants, the point being that, if it were a little different from what it presently is, we would not be alive. Since it appears unbelievable to most scientists that the universe was deliberately designed by a divine Creator to the purpose of being inhabitable by living beings provided with consciousness, it seems that *infinite space* must be allowed for a *cosmic Darwinian evolution* to occur.

So the saying goes that the "multiverse", by an ultra-rapid expansion after the "big bang", was blown up to contain "bubbles", each "bubble" being a relatively independent mini-universe ruled by laws of its own, with "natural constants varying by chance", and "mostly" isotropical. With this infinity of "baby-universes" bubbling and babbling all over infinite "super-spacetime" it would be outright incredible, Smolin opines, if not some few of them were similar to our own, and one of them is *therefore, by lucky chance*, just that particular universe we inhabit. *Heureka!* How all this confusing variety of "laws" and "constants" could possibly remain compatible with a *unitary* all-embracing quantum wave function, it is probably better to forget all about.

Accepting *the unison verdict of Plato, Cusanus, Leibniz, Kant & cet.:* ***the world is one***, we can perhaps begin to discuss seriously: are there any other ways our universe can be infinite? Already Newton confronted the question of gravitating bodies in infinite space and came to the obvious conclusion that an "island" of stars situated at rest in infinite space would be unstable; but he likewise noticed that to put an infinity of stars at permanent rest in infinite space would require a balance of forces far more precise (infinitely more) than to balance a needle on its tip. Einstein, acclaimed as the founder of modern cosmology, also wrestled with the "island world" quandary, for which he proposed his celebrated model of a static, finite, yet unbounded universe in closed, spherical space; but it was soon realized that his "needle" didn't balance either.

In his [1981], Harrison discusses all the world models compatible with general relativity: some in spherical space, an initial phase of expansion leading into a final phase of contraction, some in flat space, an initial expansion decelerating towards zero due to the brake of gravitation, and some in hyperbolic space, the expansion being accelerated towards the light speed limit. Common to all these models is their finiteness, and their conformity to the metric of Friedmann, their apparent viability *proving general relativity to be a technique* rather than a genuine theory. Against spatially infinite world-models, Harrison misinterprets an argument of Poincaré proving that any finite number of atoms must recur to their original configuration in space if rearranged an infinite number of times; this argument is only valid for certain types of dynamical systems. Personally, I share Harrison's disgust of the Nietzschean notion of an "eternal return", but so far he has not produced any serious objection against the concept of an infinite universe.

A unique model of an infinite universe, expanding uniformly at the speed of light from a so-called *transcendent point-event* ("white singularity"), was proposed by Milne; this model is infinite in the sense that it is at its present stage of development populated by an infinity of stars, but can nevertheless be described in two seemingly incompatible ways: as an expanding sphere, according to the t,r scale, and as eternally at rest in infinite space, according to the τ,ρ scale. My own preferred model is a modification of the Milne universe: a static sphere of finite radius, embracing an infinite number of galaxy groups in a steadily accelerating dispersion outwards.

Q5. DOES THE UNIVERSE EXPAND?

Many physicists and astronomers find it hard to accept the idea of an expanding universe. Thus most of the members of *ACG* (the *Alternative Cosmology Group*, *www.cosmology.info*) and *NPA* (the *Natural Philosophy Alliance*, *www.worldnpa.org*) unamiously reject the concept. The same applies to some of my close allies in the fight against Einsteinian dogma and myth; one might nourish the suspicion that their attitude is simply due to a shortage of imagination. Below, we shall marshall some important arguments in behalf of a dynamic cosmos.

The observations of Slipher and Hubble, that the light from distant galaxies is subject to a shift, increasing with distance, of spectral lines towards the red end of the spectrum, might have led Einstein to consider the possibility that this redshift could be due to a universal motion of recession or dispersion. However, the first to suggest a direct proportionality between distance and velocity for distant galaxies, called "Hubble's law", was the cosmologist Robertson in 1928. But already in 1917 - well before Eddington's dubious "confirmation" in 1919 of the bending of light rays predicted by Einstein and, ahead of him, by Newton as well - the astronomer de Sitter had predicted "a systematic displacement of spectral lines towards the red". His reason was that his own new static world model differed from that of Einstein on account of a strange property: if some free particles were sprinkled into the model's otherwise empty space, they would spread. In this way de Sitter got "motion without matter" where Einstein had "matter without motion". The bizarre ideas of rotating or oscillating universes we shall pass over in eloquent silence.

It has been pointed out that the idea of universal expansion should not be interpreted as an expansion outwards into pre-existing space, but as a steady increase of inter-galactic distances. But if we consider the Milne-model of 1933 this is not true, since this model can be depicted as a sphere expanding outwards into flat space, at the speed of light, from its apparent center, all the while distances between (groups of) galaxies are increasing according to the Hubble law. It may appear strange to say that the Milne universe is expanding into a pre-existing flat space; this would be a problem if he, with Einstein, took space to be "real", but Milne did not do that: following him, the abstract mapping of space as flat is our own free choice based on convention. In principle, *the dispersion of galaxies* should be distingusihed from *the expansion of cosmos*. This is particularly relevant when we consider my own preferred world model; with that model there is a steadily accelerated dispersion of galaxies, but no trace of a universe in expansion.

The point is that the new universe of continued creation proposed here can be compared to an instantaneous "snapshot" of the Milne universe: the cosmic sphere is no longer expanding, but has a fixed radius $\mathcal{R}_u = 2$, the limiting horizon being approximated by $\mathcal{R} = 2\,th\frac{1}{2}r,\ r \to \infty$. Nevertheless, all galaxies at rest with respect to the cosmic frame as defined by the ***CBR***, are scattered, being mutually receding in conformity with $\rho \equiv \mathcal{R}/e^{\mathcal{T}} \equiv 2\,th\frac{1}{2}r/e^{\mathcal{T}} \equiv$ *const.*, ρ being a comoving coordinate assigned by the observer to each single galaxy at the instant of calibration (as proposed by Pierseaux, their acceleration might be caused by a so-called Poincaré pressure). The imaginary *horizon* - neither an "event horizon" nor a "particle horizon" in the usual sense - by separating a *potential infinity* of *observable* galaxies from an *actual infinity* of *unobservable* non-existing zero-size galaxies, *is interpretable as a universal surface of demarcation enabling us to ascribe a well defined total energy to the cosmic sphere*. According to Rowlands [2007], the natural choice of this energy is *zero.* Seen this way *the cosmic sphere is a perfect black hole*, the energy gain at the center being balanced by a corresponding energy loss at the periphery. The cosmic redshift *solves the paradox of the dark sky at night* ("Olbers' paradox", so-called).

Q6. IS NATURE GOVERNED BY LAWS?

The concept of physical "laws" - or "laws of nature" - may sound strange to modern ears, derived as it is from such sources as Anaximander: "Whence the origin of things thence also their demise, according to necessity, for they pay penalty to each other, atoning their trespasses in conformity with the order of time." - and Herakleitos: "The Sun will not trespass its measure, or it will be prosecuted by the servants of justice/revenge". In its more modern form, of course, it is due to Newton who claimed to have deduced from experience his famous "laws of motion": 1) the law of *inertia*, 2) the law of *forced acceleration*, and 3) the law of *action and reaction*. Of these, the two first laws are contained in: $\boldsymbol{F} = d\boldsymbol{p}/dt = d(m\boldsymbol{v})/dt = \boldsymbol{v}(dm/dt) + m(d\boldsymbol{v}/dt)$, $\boldsymbol{F} = 0$ giving 1), and $\boldsymbol{F} \neq 0$ giving 2). To them we must add 4) the law of *universal gravitation*, $\boldsymbol{F} = GMm/\boldsymbol{r}^2 = m\boldsymbol{a}$, with $\boldsymbol{a} = GM/\boldsymbol{r}^2$ as the gravitational acceleration. The first equation in $\boldsymbol{F}$ may be seen as *defining* the concept of force, the last one as instantiating an example. However, "force" still remains a hazy concept within the Newtonian world system, and it is only natural that Newton after all renounced on *explaining* gravity, satisfying himself with *describing* it.

As stated by Galileo, the *Great Book of Nature* is written in the language of mathematics, and the task of natural science is to discover the true causes (*verae causae*) behind phenomena. But according to his teacher Plato - in fact: Galileo refers to Plato in several places - this is too much to expect: *concerning natural phenomena we should content ourselves with what is the more probable, instead of striving for genuine knowledge* ($\grave{\epsilon}\pi\iota\sigma\tau\acute{\eta}\mu\eta$: knowledge, or science). Descartes, a contemporary of Galileo, proposed the first law of conservation, viz. of momentum, and intimated that, if God had created only the matter of the universe together with all its laws, the end result after a temporal process of evolution would be precisely the world as we know it. A similar view of the universe as a *mechanism*, or *clockwork*, was suggested by Leibniz who replaced the Cartesian law of conservation of momentum with that of conservation of energy, called *vis viva*; nevertheless, he also warned against pushing the mechanistic viewpoint too far: as he saw it, the idea of mechanical *causality* only scratched the *surface* of phenomena.

However, in public opinion it was Hume who, by his criticism of the concept of causality understood as necessary connection, showed Newton's system to be a castle built in the air. The scandal of philosophy, unable to disclose a solid foundation for an exact science that had provided us with such deep insights about the working of nature, was a great challenge to Kant; his solution of the puzzle was to place the necessity in the human intellect instead of in nature. His contemporary Laplace, relying on his own wholly mechanistic explanation of the universe, confidently dismissed the traditional hypothesis of a divine Creator. However, thermodynamics raised new problems relating to its second law which were not solvable by statistical mechanics, whence some scientists advocated a phenomenological interpretation of that branch of physics. But the final break with the deterministic picture of the world occurred with quantum mechanics which supplemented a strictly deterministic wave equations by a purely statistical interpretation. One can say that quantum theory thereby reconciled the opposite views of Platon and Galileo.

According to common opinion, laws of nature are expressible by universal propositions - preferably mathematical equations relating to empirically defined objects or properties - that are necessarily valid for experiment and observation. The great question is whether such laws exist. Maybe chance is fundamental, so that all apparent laws are nothing but statistical regularities? This view is corroborated by Milne's theory: in his ***KR***, the laws of gravity and electrodynamics are *statistical habits of nature induced by cosmic asymmetries*, cf. van Fraassen [1989].

Q7. ARE OCCURRENCES PREDESTINED?

Even if the fundamental laws of quantum mechanics allow only probabilistic predictions, there are arguments for determinism - indeed fatalism - of another and very different character, a famous example being the "*master argument*" of the antique philosopher Diodoros Kronos. According to Diodoros, the following trilemma is inconsistent: 1) From the possible does not follow the impossible. 2) If something is or was the case, it will necessarily have been the case. 3) Something is possible which is not the case and never will be the case. Assuming 1) & 2) to be indispensable, he claimed the falsity of 3) to be provable; hence follows that, if something is possible, it either is the case or in some future will be the case. With plausible interpretations of 1) & 2) it can be shown formally that Diodoros was right, cf. Øhrstrøm & al. [1995], granted that not only the past, but also the future, is linear; thus it follows that the master argument can be circumvented if time is conceptualized like a "tree" with infinitely branching future possibilities. Another argument of less sophistication, but much better known, is the so-called *lazy argument* which might run somewhat like this: "Whatever I do is written in the stars (or in spacetime, e.g.) If an accident hits me it is written in the stars. If it does not hit me this is written in the stars too. So, whatever I do, I can't help it". This type of argument was countered effectively by Aristotle:

According to Aristotle (*De Interpretatione ix*): *If a man says that something will be, and another that it will not be, then it is clearly necessary that one of them must be telling the truth, i.e., if every assertion is either true or false but not both at the same time .. On this assumption nothing exists or happens by chance .. nor will anything in the future be or not be by chance .. but everything will happen of necessity .. Therefore it was always true to say of anything that has happened that it would happen. But if it was always true to say that something was or would be so, it is impossible for it not to be so or not to be going to be so .. Thus it is necessary that everything which is going to happen must happen .. If this holds, there is no need for us to reflect on or aspire for anything, assuming that if we do this will happen and if not it will not .. But these consequences are impossible. We know that future things do stem from our choices and actions .. Therefore, clearly, not everything is as it is, or happens as it does, of necessity .. So, what I think is something like this: Necessarily, either there will be or there will not be a seabattle tomorrow; but (from this it does not follow) that, necessarily, there will be a seabattle tomorrow, nor (does it follow) that, necessarily, there will not be a seabattle tomorrow.*

This argument against fatalism, showing the fallacy of distributing the necessity operator over a disjunction, can be supplemented with the following modern interpretation of quantum theoretical probability in terms of a tempo-modal concept of future directed possibility:

Probabilities are intimately related to the future. They are a form of what might be called 'presentness of the future'. The future is present in the form of possibility. Statements regarding possibility and probability are neither 'subjective' .. nor 'objective' .. but rather 'objective in a subject related way', that is, they can only be formulated on the basis of a certain knowledge, but they are then testable by anybody which is in possession of that knowledge. In a 'monistic' philosophy of mind and matter .. this kind of 'subjectivity' is characteristic of all sorts of being. The reduction of the wave packet is nothing but a gain of information based on new knowledge. The apparition of paradox has only emerged because the meaning of the Ψ-function as being 'subject related in an objective way' was not properly acknowledged. What is then left to ponder is only a quantum theoretical description of knowledge itself. (My translation, MTW)

C.F. von Weizsäcker [1992] p.890.

Q8. IS GRAVITATION INSTANTANEOUS?

According to Rowlands, the speed of the force (not the waves) of gravity must be infinite; cf. van Flandern: *The Sun's gravity emanates from its instantaneous true position, as opposed to the direction from which its light seems to come ... No relativist has as yet, to my knowledge, devised a theory to explain how it can be that the direction of the Sun's gravitational force and the direction of photons arriving from the Sun are not parallel.* See Rowlands [2007] p.448.

This contradicts the premisses of Einstein's General Relativity (***GR***). In Rowland's view: ***GR*** is "not a theory of gravity at all". It actually provides no physical mechanism for the action of the gravitational force; much rather it just exposes the way in which gravitation is measured. Neither does it replace the Newtonian theory, rather it makes use of it by requiring that the weak field limit of the gravitational potential be the Newtonian value, which must be put in by hand. In fact, the field equations of ***GR*** merely describe the curvature of space-time mathematically, having no real physical relation to gravity at all. The only bond between curvature and gravity is tied when the classical potential is inserted by hand into the drastically simplified equation for the radial field surrounding a point-source, the so-called Schwarzschild-solution; ibid.p.452.

But Rowland's criticism of General Relativity does not stop here; on p.478, he stresses that hard problems are associated with the idea that General Relativity is necessarily nonlinear:
As a nonlinear theory it declares its own unreliability by producing unrenormalisable infinities.
It is too difficult to handle for cosmology and black hole physics without drastic simplifications.
It is unable to give a full description of gravity even in principle, and modifying it is of no avail.
It invites the possibility of a unified field theory, but as such it is nothing but a hopeless failure.
It neglects the fact that the original solution by Schwarzschild, approved by Einstein, was linear.
It destroys the foundation of a series of important symmetries that would be natural without it.
Taken seriously, it predicts the immediate closure of a universe filled up with zero-point energy.
Defined as the first stage in an unending number of best-fit models, it excludes a unified theory.
Contradicting a nonlocality corroborated by experiment, it is incompatible with quantum theory.
Finally it has lead to the perverse idea that high-brow math is needed at a fundamental level.

Rowlands explains the generation of particle masses with reference to the standard model extended by the so-called Higgs-mechanism. This may seem perfectly natural, until one recalls that the Higgs-particle has played "hide-and-seek" with the experimenters for quite a long time and, if it is not to be found, it may be necessary to invent another, i.e. "Higgs-less", explanation. Following Rowlands, *unless one believes in some extreme version of the anthropic principle, the laws of physics, in* ***a unified theory****, must be true in all places at all epochs*, ibid.p.600. Except that Rowlands deliberately eschews cosmological models, his stance as just expressed is very much in line with *the ideas behind the model of continued creation* presented in this book. Further, his claim that the gravitational force is instantaneous agrees very well with the view of Milne that gravitation is a spontaneous consequence of local deviations from global symmetry: *in a kinematic universe there is no gravitational attraction between fundamental particles.* But Rowlands wants to derive inertia from gravity, following Mach's principle, whereas I find it more natural to derive gravity from inertia, in opposition to Mach, but in agreement with Milne. The only question is if Milne's kinematic method is applicable to a physics based on something like the remark just quoted - cf. the so-called "perfect" cosmological principle of Gold & Bondi. At least it is clear that the stability of such a physics must be able to allow statistical variations of an enormous size in order to be compatible with current astronomical observations.

Q9. IS TIME CAUSALLY DEPENDENT?

There is a widespread tendency in contemporary philosophy of science to see causality as well as causal order and connectivity as being more fundamental than time and temporal order. In order to discuss this attitude properly we have to settle on a plausible definition of causality; but this is not easy, there being at least three distinct and very different theories of that concept: 1) the *probabilistic* theory, 2) the *counterfactual* theory, and 3) the theory of *covering law*.

Against all theories it can be objected (assuming what is doubtful, viz. that they indeed pretend to explain time in terms of causality) that they presuppose what they attempt to explain. As regards the probabilistic theory it must be stressed that it is hard to see how the concept of probability can be ascribed any meaning concerning events which are present or past already. Relating to the counterfactual theory it must be understood that the notion of a counterfactual course of events involves the notion of past facts as being now unpreventable and irrevocable together with the very speculative imagery of past-future events that are no longer possible but which might under other circumstances have been possible at an earlier stage of development. With regard to the covering law theory we must distinguish between laws of classical mechanics which are reversible and deterministic, giving no clue to the difference between earlier and later, and the laws of thermodynamics where at least the second law is itself in need of a clue as to which of the two directions of time should be viewed as leading towards increase of entropy. That the laws of quantum mechanics are themselves indifferent to temporal order is irrelevant in so far as a "wave function collapse" is requisite to the production of an observational fact.

However, there is a fourth theory of causality based on the *mark method* of Reichenbach. In his [1958] p.136, he claims to have given a time independent definition of cause and effect, so that the relation of cause to effect can be utilized to define the relation of earlier to later. Starting with a notion of causal connection $C(E_1, E_2) \simeq C(E_2, E_1)$ which is neutral to time, he describes the *causal order* of events E_1 & E_2 thus: if a small variation of E_1 to E_1^* is compatible with a small variation of E_2 to E_2^*, but not the other way round, then E_1 is cause and E_2 effect. In other words: the combinations E_1E_2, $E_1^*E_2^*$, $E_1E_2^*$ may all occur, but never this one: $E_1^*E_2$. So, apparently, we have a fool-proof definition of the temporal order in terms of the causal one. Unfortunately, it is easy to produce an exceedingly simple counter-example to this definition: drop a pea into a round bowl, vary the throw as much as you wish, then, the pea having rolled forth and back a few times, the result will always be the same: a pea in the center of the bowl! To be honest: I consider this whole enterprise to be thoroughly implausible and highly suspect, the only reasonable option being to give it up, defining causal order in terms of time instead.

Now, granted that temporal order is prior to causal order, how do we define causality? The best choice is to define it in terms of *physical laws*, and the definition I propose is this one: Consider *a well defined energetic system subject to laws determining its development* in time; granted that the *various stages* of this development display a clear and distinct *temporal order*, we shall say that *any earlier stage is causally connected to any later stage*, the earlier one being the *cause* of the later one, the later one being the *effect* of the earlier one. Of course, we have to distinguish between laws that are *deterministic* or merely *probabilistic*, in the sense of statistical mechanics or in that of quantum mechanics, just as we have to distinguish between conditions that are *necessary* to produce an effect and conditions that are *sufficient* to produce the effect. In my view, *this is the only precise definition of causality that can be given and, if the world is a system of zero energy, the definition allows us to see it as a causal chain of world-states.*

Q10. DOES TIME INVOLVE CHANGE?

The aim of *science* is to *describe* the present, to *predict* the future, and to *explain* the past, and the difference between science and superstition depends on the way of performing this task. Thus science *presupposes the tripartition of time in past, present and future* - nevertheless, the distinction between *determined* (past-present) and *undetermined* (future) will probably suffice. The question of *tenses* is thereby placed in the focus of our attention. I will not hesitate to brand the widespread view that tenses are fictitious as a particularly pernicious sort of superstition.

Another view, rather more plausible at a first glance, is that time is subordinate to change. Aristotle, for instance, defined time as "the number of motion with respect to before and after". Now, to Aristotle, motion meant change, and so he distinguished four different kinds of change: a) change of *substance*, b) change of *quality*, c) change of *quantity*, and d) change of *locality*, going from essential motion to superficial motion. It is ironical that the origin of modern science was conditioned by a changing attitude towards viewing spatial motion as the fundamental one; this explains why spatially extended objects were considered to be basic. But even more ironical is it that the majority of today's scientists without reflection accept Aristotle's equally outdated view that the question of existence refers to things defined as objects with changing properties. Modern logic has long ago complied with the fact that objects are conceptual constructs devoid of any inherent substantiality, confirming that only statements - not things - can be true or false. Why then do physicists - Einstein, Podolsky & Rosen, e.g. - still argue in behalf of a realism that is naïve in the sense that it assumes the existence of objects - quantal systems - that after having been connected in the past by an event of interaction are no longer entangled, but independent? Why not just accept that quantum theory has put an end to the old ideal of objectivity?

The solution to this impasse is simple and natural. Don't ask what is! Ask what happens! What happens we call *events* and events, present or past, are *facts* whether perceived or not. Stricly speaking, only statements - specific linguistic expressions - can be bearers of truth-value; this seems to involve something like human consciousness, so we are at the point where *matter* meets *mind*, and this is why the Copenhagen interpretation of quantum theory, claiming that physics does not care about reality but about our *knowledge* of reality, was felt so provocative. We already opened the possibility of *facts unperceived* by human observers; maybe we can also mitigate Bohr's claim so as to accept *knowledge* which is *expressible* but not actually *expressed*, for the moment ignoring that this comes close to accepting that mind is a *potentiality* of matter. Noticing that "the first object, to which such a theory (i.e. 'abstract quantum theory') is related, is not a *thing*, but a *stream*", Weizsäcker [1985] p.363, further, that "in the (concrete) quantum theory, the spatiality of objects is only a derived/secondary property", ibid. p.391, and, finally, that "if the quantum theory is taken seriously from the mathematical point of view then, stricly, there are no separate objects, but an (entagled) whole", Weizsäcker [1992] p.329, it is natural to ***conceive of reality as a temporal flow, or stream, that is broken up by the tripartition of time*** into *present events* which are *just now* made actual, *irreversible facts* which are *inevitably past*, and *future possibilities* which *may or may not be realized.* From this we construe our objects, ***and for this reason the change of temporal modalities is primary to any other kind of change.*** Weizsäcker has axiomatized quantum theory and special relativity in terms of temporal logic. Of course, the bare change of tense operators as applied to statements is in itself vacuous if the statements themselves are empty and nothing whatever is true, meaning truth does not "exist". This would be the case if "facts" were reversible. We shall ignore this weird speculation.

Q11. IS SIMULTANEITY UNIVERSAL?

When an event X is happening, another event Y either has happened or not happened - 'having happened' is not the kind of property that can attach to an event from one point of view but not from another. On the contrary, it's something like existing; in fact to ask what has happened is a way of asking what exists, and you can't have a thing existing from one point of view but not existing from another, although of course its existence may be known to one person or in one region, without being known to or in another. So it seems to me that there's a strong case for just digging our heels in here and saying that, relativity or no relativity, if I say I saw a certain flash before you, and you say you saw it first, one of us is just wrong - or misled it may be, by the effect of speed on his instruments - even if there is just no physical means whatever of deciding which of us it is. To put the same point another way, we may say that the theory of relativity isn't about real space and time, in which the earlier-later relation is defined in terms of pastness, presentness, and futurity; the 'time' which enters into the so-called space-time of relativity theory isn't this, but is just part of an artificial framework which the scientists have constructed to link together observed facts in the simplest way possible, and from which those things which are systematically concealed from us are quite reasonably left out. This sort of thing has happened before .. When .. the differential calculus was first invented, its practitioners used to talk a mixture of excellent mathematics and philosophical nonsense, and at the time the nonsense was exposed for what it was by the philosopher Berkeley, in a pamphlet entitled 'A Defence of Free Thinking in Mathematics' .. The mathematicians saw in the end that Berkeley was right, though it took them about a century and a half to come round to it. They came round to it when they became occupied with problems which they could solve only by being accurate on the points where Berkeley had shown them to be loose; then they stopped thinking of the things he had to say as just a reactionary bishop's niggling, and began to say them themselves. Well, it may be that some day the mathematical physicists will want a sound logic of time and tenses; and meanwhile the logician had best go ahead and construct it, and abide his time.
A.N. Prior, founder of tense logic, Wegener [1999]; W. & al. [1996], Lucas [1999]; cf. ***Q15***.

Interviewer: *Bell's inequality, as I understand it, is rooted in two assumptions: the first is what we might call objective reality - the reality of the external world, independent of our observations; the second is locality, or non-separability, or no faster-than-light signalling. Aspect's experiment (indicates that one of the two has to go. Which one would you stick to?)*
John Bell: *I think it's a deep dilemma, and the solution of it will not be trivial. It will require a substantial change in the way we look at things. But I would say that the cheapest resolution is something like going back to relativity as it was before Einstein, when people like Lorentz and Poincaré thought that there was an aether - a preferred frame of reference.*
Quotation from interview in Brown & Davies, eds.: *The Ghost in the Atom*, Cambridge 1987.

Ein systematischer Aufbau (der Physik) würde verlangen dass zuerst die vollständige Logik zeitlicher Aussagen entwickelt und auf sie dann erst die physikalischen Theorie gegründet wurde .. Die These dieses Buchs ist, dass eine Logik zeitlicher Aussagen fundamental selbst für die Begründung der klassischen Logik sein sollte; dass diese zeitliche Logik in den Ausdrucksweisen der Umgangssprache, vielleicht am deutlichsten in den indogermanischen Sprachen, schon implicite enthalten ist; dass die Quantenlogik eine spezielle Fassung diese zeitlichen Logik ist; und dass insofern die Quantentheorie nur der Anlass war, der uns zu dieser logischen Reflexion veranlasst hat. C.F. von Weizsäcker: *Aufbau der Physik* [1985] pp.52&313.

Q12. IS THE WORLD CONTINGENT?

For centuries, if not millennia, it has been the aim of philosophers and physicists to invent a theory of the cosmos presenting it as a self-explaining mechanism, cause of its own existence. It being impossible to devise a *perpetuum mobile* from a particular isolated energetic system, maybe one could construct the whole universe as such? Isn't the universe itself just *causa sui*? In that case all the divine prerogatives could be transferred from God to his supposed creation: nature itself could be considered the only God, as Spinoza, Hawking, and others, would have it. One scientist who, in my view, has made one of the most promising attempts in this direction, is P. Rowlands [2007]. Without knowing his attitude to metaphysical issues precisely, I have no doubt that his ambition to construct a Unified "TOE" (theory of everything) is very high.

According to Rowlands (p.2f.), "we cannot devise a unified theory simply by combining quantum mechanics and general relativity in a new mathematical superstructure", such attempts being doomed to fail because partial theories are not unified by combining them but by deriving them from a common origin: thus *zero* must be the point of *departure* as well as that of *arrival*. Only the notion of *nil*, or *nothing*, split up into *duality*, is radical enough to explain *everything*. From the point of view of physics (p.84f.), "the Dirac nilpotent equation would seem to be a perfect way of producing something from nothing", since it incorporates all groups of interest; and the conservation laws implied by $(\boldsymbol{k}E + i\boldsymbol{i}\boldsymbol{p} + i\boldsymbol{j}m)(\boldsymbol{k}E + i\boldsymbol{i}\boldsymbol{p} + i\boldsymbol{j}m) = 0$, by including mass-energy and the three kinds of charge, determine the full behaviour of all physical systems. Basing our mathematics not on the integers, but on an immediate zero totality, we may produce "a mathematical structure .. avoiding the incompleteness indicated by Gödel's theorem."

Elaborating on this (p.556f.), Rowlands proposes to start with *one symbol* representing 'nothing', and *two basic rules* (duals of a single rule): 1) *create*, a process adding new symbols, and 2) *conserve*, a process examining the effects of any new symbol on those already existing, to ensure a zero sum again. He furthermore points out that *a nilpotent universal computational rewrite system (NUCRS),* working on an infinite alphabet that defines the semantics of quantum mechanics in terms of a universal grammar, *may suffice to determine the structure of cosmos, the genetic code, the human brain, and human language.* The *NUCRS* may thereby enable us to establish an *Evolutionary Anthropic Semantic Principle* that can describe the rules by which a sentient being is able to comprehend *Nature's Own Rules*. So Rowlands suggests the method of a "bootstrap" to perform the ultimate trick: *Ouroboros*, a snake eating itself from the tail.

I deeply admire the daringly intrepid and exceedingly original construction of Rowlands. If anyone should ever succeed in mapping the invariant rules and numerical relations of nature, it would probably be him ahead of Penrose, Hawking, Barbour, Smolin, Isham or whoever else. But how shall we assess his claim that *NUCRS* can avoid the incompleteness theorem of Gödel? The prospect of a *closed physical system*, complete with fully integrated syntax and semantics, containing a unified description and explanation of *both mind and matter*, is not very bright:

"We may note here that it *is* possible to construct a calculus rich enough in its symbolism for the statement within itself of its .. own *syntax* .. (but not of) its *semantics* .. It cannot be said within any system .. that the system is *complete* .. i.e., its unproven theses and rules suffice to prove all theses (that) are true for all interpretations of their variables." - A.N. Prior [1962] p.70. Prior's proof is very simple and, as stated, particularly applicable to Rowland's rewrite system.

Even if Rowlands had succeeded in mapping all the invariant laws and pure numbers of all possible worlds, ***the abyss between possibility and factuality*** *would not be bridged ...*

Q13. IS NATURE ATEMPORAL?

Einstein is reported to have said often that the problem of the 'now' worried him seriously. The problem is that physics cannot mark out an instant as being different from another instant, and this holds even if we disregard the 'spatialization' of time which was a direct consequence of the spacetime formulation of special relativity, although this naturally accentuated the problem. Physical 'time' is measured by clocks counting (by the ordinal numbers) the recurrence of events that are regulated by cyclic processes, by increase of entropy, or by the disintegration of atoms. Attempting to disclose the laws governing the causal chains between dated events, physicists ordinarily presuppose that such counting of 'time' is indifferent to their choice of 'temporal' zero. However, this supposed *homogeneity of 'temporal intervals'* may be valid for the master clocks of *fundamental observers* without being valid for the slave clocks of *accidental observers*.

Now many modern physicists, especially those influenced by the grumblings of Einstein, are inclined to regard physical 'time' as an *illusion* in the sense that it cannot be ascribed a fixed direction; whence follows that the usual notion of 'temporal flow' must be even more deceptive. This view is supported by a famous (notorious) argument of McTaggart (repeated by Mellor) who ingeniously distinguished between the *absolutist A-concepts of past/present/future* and the *relationist B-concepts of before/during/after*. A deep logical chasm has ever since separated the *A-theorists*, who insist to explain the *B-series* in terms of the *A-series*, from the *B-theorists*, who attempt to interpret the *A-series* in terms of the *B-series*. Today it is a commonplace to distinguish 'tensers' from 'detensers'; but it was A.N. Prior, the founder of modern tense logic, who first gave logical import to this distinction. According to Prior, *all real existence is present*, and *only present existence is real*, the past being no longer real and the future being not yet real, just as *facts* are *true statements*, and statements, if true, are *true now*, i.e. when said or read.

As it is, *A-theorists* or 'tensers' (like Prior, e.g.) would attempt to reduce talk of instants to tensed propositions, whereas *B-theorists* or 'detensers' (like Quine, e.g.) would attempt to reduce tenses to predicates of existing instants. A sort of "half-way house" in between is taken up by 'neutralists' who prefer to treat these two positions on a par. Among the A-theorists we can further distinguish 'moderates' from 'radicals': while the former would insist on using modal primitives together with the tenses, the latter would follow Prior in his attempt to define modalities by means of tenses. Taken together, all these distinctions give rise to *four grades of tense-logical involvement*, Prior [2003], ch.xi. The system $\mathcal{W}$ proposed in ***Q15***, by extending the tense-logical system for future branching time with Peircean definitions of temporal modalities and adapting it to deal with the problem of non-statability, goes full way to the fourth grade.

Given some present fact, what are we able to infer with respect to its past and its future? It is a fact that you are just now reading a chapter from a book on *Non-Standard Relativity*. From this fact you can infer not only that it will always have been the case that you were reading in that book, but that it is now inevitable / unpreventable, that it will have been the case. However, you cannot infer that it was always the case that you would once read in this book, merely that since you learned reading it was always possible that you might once read in a book; but even that you could not infer if you belonged to an age before the art of writing was known. Our logic thereby makes sense of ***the flow of time*** by separating the now from past and future: what belongs to the past is no more possible, what belongs to the future is not yet realized, but, in pace with possibilities being annihilated, new factual truths are being created just now!

Q14. DOES TIME FLOW?

The aim and purpose of ***tense logic*** is to systematize reasoning with tensed propositions. In order to do so properly we must distinguish between two types of statements:

1) temporally definite statements - i.e. sentences with invariant truth-value

2) temporally indefinite statements - i.e. sentences with variable truth-value

Against this distinction it has been objected that statements of the second kind are not proper propositions, but propositional functions left undetermined due to their lack of dating. But that objection can be dismissed as soon as we give attention to their context.

Tense logic, or ***the logic of change***, is relevant when we study statements in their natural context which is a context of temporal change. What we experience is reality in change and, just as reality itself is emerging and expiring, thus our language, in order to represent this perpetual change, must reflect it in the successive origin and closure of the truth of its assertions. The stuff of tense logic consists mainly of temporally indefinite statements, the definite statements being those which are omnitemporal, those which mark an absolute beginning or an absolute ceasing, and those that are unique in the sense that they are true *now*, but neither true in the past nor in the future. With tense logic the verb, or copula, can no longer be interpreted as timeless, but should always be understood as referring to the present: it is *now* the case that so-and-so.

It is our aim to sketch a new system $\mathcal{W}$ of tense logic which is *indeterministic* not merely in the sense that it permits possibles to branch towards the future, but also in the sense that it, more radically than standard tense logic, discards the idea of timeless truth by implying truth to emerge in time along with reality. Truth is nevertheless assumed to be eternal in the sense that, once established, it can never be annulled or suspended, but is valid henceforth, i.e. in all future. We shall see it as a virtue of our system $\mathcal{W}$ if it succeeds in reproducing the richest variety of linguistic forms by the simplest possible expense of axioms. The system will display features derived from Aristotle, Diodoros, Aquinas, Leibniz, Kierkegaard, Peirce, and Prior.

$\boldsymbol{K_t}$ *&* $\boldsymbol{K_b}$ are two very simple tense-logical systems of which soundness and completeness are provable with respect to a Leibnizian *possible-worlds* semantics as demonstrated by Kripke. But, with $\boldsymbol{K_b}$, time acquires a direction so that we can speak of ***the arrow of time***, and for this reason alone it is natural to give priority to $\boldsymbol{K_b}$, ahead of $\boldsymbol{K_t}$. $\boldsymbol{K_b}$ is characterized by a successive loss of possibility. The actualization of only one among an infinity of future possibilities means that most of the conceivable futures are successively eliminated. Hence what was possible in the past may now be excluded. But, making use of Prior's concept of statability, we shall claim that this perpetual loss of possibility is compensated by a steady increase in the sum of statable truth. This lends support to the view that ***the passage of time*** is mind-independent.

Exemplifying the statability of a proposition p by the tautology $p \Rightarrow p$, we insist that the sum of statable truth is steadily increasing due to the fact that assertions which were not hitherto statable are becoming statable in the course of time. Being now statable, we shall assume that they henceforth remain statable, so that propositions feigning departed individuals to be present are just false. Granted this, we shall claim that what is true now will inevitably have been true. By contrast it is uncertain whether what is now statable was always statable, so often we cannot know if what is true now was always going to be true. Our system $\mathcal{W}$ thus makes a difference between past and future in the sense that the continued loss of possibilities is compensated by a successive gain of statable truth. In this sense we can speak of a ***creation of truth***.

Q15. WHAT IS TIME?

AXIOMATICS FOR TEMPO-MODAL LOGIC: *The System $\mathcal{W}$*

PRELIMINARIES

1. *Atomic propositions are well formed formulae, wff.*
2. *The set $\mathcal{W}$ of atomic propositions π contains a subset of abstract propositions τ called 'instants' or 'dates', and one unique proposition ω called 'the world'.*
3. *Instant-propositions may be distinguished by their index, e.g. τ by τ_i*
4. *If α, β, and τ are wff, then $\neg\alpha$, $\alpha \Rightarrow \beta$, $N\alpha$, $H\alpha$, $\Pi\tau_i$: α, are wff:*
   for '$\neg\alpha$' read: 'not α' or 'it is not the case that α'
   for '$\alpha \Rightarrow \beta$' read: 'if α (is the case), then β (is the case)'
   for '$N\alpha$' read: 'henceforth α' or 'α will always obtain'
   for '$H\alpha$' read: 'hitherto α' or 'α did always obtain'
   for '$\Pi\tau$: α' read: 'at all instants / dates τ: α'
5. *No other formulae except those above and their combinations are wff*

DEFINITIONS & RULES

df $\vee$ $\alpha \vee \beta \equiv \neg\alpha \Rightarrow \beta$ *read: '(either) α or β' $\equiv$ 'if not α, then β'*
df $\wedge$ $\alpha \wedge \beta \equiv \neg(\alpha \Rightarrow \neg\beta)$ *read: '(both) α and β' $\equiv$ 'not: if α, then not β'*
df $\Leftrightarrow$ $(\alpha \Leftrightarrow \beta) \equiv ((\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha))$ *'α iff β' $\equiv$ 'if α then β, and if β then α'*
df P $P\alpha \equiv \neg H \neg\alpha$ *read: 'past α' $\equiv$ 'not hitherto not α'*
df M $M\alpha \equiv \neg N \neg\alpha$ *read: 'maybe α' $\equiv$ 'not henceforth not α'*
df L $L\alpha \equiv HN\alpha$ *read: 'forever α' $\equiv$ 'α is necessary' $\equiv$ 'in all past future: α'*
df K $K\alpha \equiv \neg L \neg\alpha$ *read: 'once α' $\equiv$ 'α is conceivable' $\equiv$ 'not necessarily not α'*
df P_{τ_i} $P_{\tau_i}\alpha \equiv P(\tau_i \wedge \alpha)$ *read: 'α did occur at τ_i' $\equiv$ 'past: τ_i and α'*
df M_{τ_i} $M_{\tau_i}\alpha \equiv M(\tau_i \wedge \alpha)$ *read: 'α may occur at τ_i' $\equiv$ 'maybe: τ_i and α'*
df K_{τ_i} $K_{\tau_i}\alpha \equiv K(\tau_i \wedge \alpha)$ *read: 'α might occur at τ_i' $\equiv$ 'conceivably: τ_i and α'*
df F_{τ_i} $F_{\tau_i}\alpha \equiv \{M\tau_i \wedge N(\tau_i \Rightarrow \alpha)\}$
read: 'inevitably: α at τ_i' $\equiv$ 'maybe τ_i, and henceforth: if τ_i then α'
df D_{τ_i} $D_{\tau_i}\alpha \equiv \{K\tau_i \wedge L(\tau_i \Rightarrow \alpha)\}$
read: 'necessarily: α at τ_i' $\equiv$ 'once τ_i, and necessarily: if τ_i then α'
df $<$ $\Pi\tau_i\Pi\tau_j : (\tau_i < \tau_j) \equiv L\{(\tau_i \Rightarrow M\tau_j) \vee (\tau_j \Rightarrow P\tau_i)\}$
read: for all τ_i and τ_j: 'τ_i before τ_j' $\equiv$ 'forever: if τ_i then $M\tau_j$ or if τ_j then $P\tau_i$'

RN $\vdash \alpha \rightarrow \vdash N\alpha$ *if α is a thesis then $N\alpha$ is also a thesis*
RH $\vdash \alpha \rightarrow \vdash H\alpha$ *if α is a thesis then $H\alpha$ is also a thesis*
with the proviso that $H(\pi \Rightarrow \pi)$ for all π in α (no value gaps)
MP $\vdash \alpha$ & $\vdash (\alpha \Rightarrow \beta) \rightarrow \vdash \beta$ *if α and $(\alpha \Rightarrow \beta)$ are theses, then β is a thesis*
$R\Pi 1$ $\vdash \phi(\tau) \Rightarrow \alpha \rightarrow \vdash \Pi\tau: \phi(\tau) \Rightarrow \alpha$ *if $\phi(\tau) \Rightarrow \alpha$ is a thesis, it is so for all τ*
$R\Pi 2$ $\vdash \alpha \Rightarrow \phi(\tau) \rightarrow \vdash \alpha \Rightarrow \Pi\tau: \phi(\tau)$ *if $\alpha \Rightarrow \phi(\tau)$ is a thesis then also $\alpha \Rightarrow \Pi\tau: \phi(\tau)$*
with the proviso that τ is not free in α
RS *the general rule allowing the substitution of equivalents*

AXIOMS FOR PC (The Propositional Calculus - Lukasiewicz)

$P1$ $(\neg\alpha \Rightarrow \alpha) \Rightarrow \alpha$ *read: 'if, if not α then α, then α'*
$P2$ $\alpha \Rightarrow (\neg\alpha \Rightarrow \beta)$ *read: 'if α, then, if not α then β'*
$P3$ $(\alpha \Rightarrow \beta) \Rightarrow ((\beta \Rightarrow \gamma) \Rightarrow (\alpha \Rightarrow \gamma))$ *'if, if α then β, then: if, if β then γ, then, if α then γ'*

AXIOMS FOR THE SYSTEM K_b (Future Branching Possibility - Kripke, Prior)

$A1$ $\alpha \Rightarrow NP\alpha$ [$A1$ entails $MH\alpha \Rightarrow \alpha$]
read: 'if α, then inevitably past α'
$A2$ $\alpha \Rightarrow HM\alpha$ *if* $H(\pi \Rightarrow \pi)$ *for all* π *in* α [$A2$ entails $PN\alpha \Rightarrow \alpha$ with proviso]
read: 'if α, then hitherto maybe α, granted that all π in α were hitherto always statable'
$A3$ $H(\alpha \Rightarrow \beta) \Rightarrow (H\alpha \Rightarrow H\beta)$ [$A3$ claims distributivity of H]
read: 'if hitherto: if α then β, then: if hitherto α then hitherto β'
$A4$ $N(\alpha \Rightarrow \beta) \Rightarrow (N\alpha \Rightarrow N\beta)$ [$A4$ claims distributivity of N]
read: 'if henceforth: if α then β, then: if henceforth α then henceforth β'
$A5$ $MP\alpha \Rightarrow (\alpha \vee M\alpha \vee P\alpha)$ [$A5$ claims linearity of the past]
read: 'iff maybe past α, then α or maybe α or past α'
$A6$ $N\alpha \Leftrightarrow NN\alpha$ [$A6$ claims transitivity and density of M]
read: 'iff henceforth α, then henceforth henceforth α'
$A7$ $H\alpha \Leftrightarrow HH\alpha$ [$A7$ would be provable with unconditioned RH]
read: 'iff hitherto α, then hitherto hitherto α'
$A8$ $N\alpha \Rightarrow M\alpha$ [$A8$ claims: inevitability implies possibility]
read: 'if henceforth always α, then maybe α'

AXIOMS FOR THE SYSTEM S5 (Omni-Temporal Necessity - Leibniz, Lewis)

$L1$ $L\alpha \Rightarrow \alpha$ [$L1$ is derivable from *df*L, $PC1$-3, $A2$, $A6$]
read: 'if forever α, then α'
$L2$ $L(\alpha \Rightarrow \beta) \Rightarrow (L\alpha \Rightarrow L\beta)$ [$L2$ is derivable from *df*L, $PC1$-3, $A3$, $A4$]
read: 'if forever: α implies β, then forever α implies forever β'
$L3$ $KL\alpha \Rightarrow L\alpha$ [$L3$ is the basic characteristic of system ***S5***]
read: 'if it only might be that forever α, then forever α'

AXIOMS FOR INSTANT-PROPOSITIONS (Abstract Dates - Wegener)

$T1$ $\Pi\tau_i$: $(\tau_i < \tau_i) \Rightarrow \alpha$ *'instant-propositions are unrepeatable'*
$T2$ $\Pi\tau_i\Pi\tau_j$: $(\tau_i < \tau_j) \vee (\tau_j < \tau_i)$ *'the order of instant-propositions is linear'*
$T2$ & df $<$ entail this corollary: *'instant-propositions are necessarily statable'*

AXIOMS FOR THE WORLD ('The Now' - Meredith)

$N1$ ω *'the world is present'*
$N2$ $L\omega \Rightarrow \alpha$ *'the world is contingent'*
$N3$ $\alpha \Rightarrow L(\omega \Rightarrow \alpha)$ *'the world is universal truth', i.e.*
'the world necessarily comprises everything true just now'

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Oh source of grace who granted me the courage
to look so steadfast on thy blaze eternal
that all my power of vision was exhausted!
Within thy depths I clearly saw collected
all leaves that in the universe are scattered
bound up with love as in a single volume!
Dante Alighieri: The Divine Comedy, canto xxxiii 82f.

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