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On the Evolution of Natural Laws

YURY V. BALASHOV

ABSTRACT

Poincaré's argumentation in favour of essential invariability of the fundamental laws of nature is critically examined. It is contended that within the realist framework Poincaré's arguments lose their apodictical force. In this sense the assumption of inconstancy of even the fundamental laws of nature is methodologically legitimate.

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1 INTRODUCTION

By now it has become clear that the idea of historicism must be looked upon as one of the cornerstones in the foundations of physical inquiry. According to Ilya Prigogine and Isabelle Stengers [1984], we witness a real conceptual revolution: scientific rediscovery of time. The most interesting manifestations of this breakthrough take place in the two fundamental disciplines—nonlinear irreversible thermodynamics and cosmology.

Much was said of the local aspect of the new 'process' worldview related to the theory of self-organization. But apparently insufficient attention was given to its global cosmological issues. Meanwhile, it is present-day cosmology that leads to raising many questions essential to 'process thinking'. The particular importance of such questions is doubled due to the intensive interplay between cosmology and particle physics in understanding the processes at work at the first moments of cosmic evolution.

In this remarkable symbiosis one can see but a modern implication of the traditional interrelationship of diachronic and synchronistic descriptions inherent in cosmological thinking since the mythopoetic epoch. In the early Universe particle physics has found an 'accelerator for the poor' where the extreme physical conditions, which can be duplicated in no terrestrial laboratory, were naturally realized, which is absolutely necessary for testing unified gauge theories. Cosmic expansion is associated with the temperature decrease. That is why in the course of the early universal history the inverse temporal unfolding of unifying mechanisms, and hence the separation of interactions, occur. Particle theories 'placed' in the rapidly changing conditions of the early Universe assume a 'diachronic dimension'. The simplest and perhaps the only possible way to test them is to calculate the most fundamental physical processes at work during the earliest evolutionary stages and to compare their cosmological predictions which the situation now observed. As a matter of fact, an overall astronomical pattern of the Universe (including our own existence therein) is nothing but a grandiose consequence of events that happened at this early epoch. They are described by the unified gauge theories immersed in the 'flow of time', *i.e.* in the non-stationary expanding and cooling environment.

The first signs of cooperation between micro- and megaphysics were already present in the late 1940s in the eminent papers on primordial nucleosynthesis by George Gamow and his disciples. In the present situation physics may transcend the trivial idea of the evolutionary origin of the substratum aspects of the Universe. It may be quite possible to extend evolutionary notions to the *nomic* features of our world, *e.g.* the particles' quantum parameters and the values of coupling-constants. Some of these quantities could perhaps vary during the early stages of cosmic evolution. The currently popular inflationary scenarios, for example, widely exploit phase transitions associated in the unified quantum field theories with the abrupt change in fundamental symmetries and hence in the particles' properties and their interaction dynamics. As Steven Weinberg put it, there is probably a 'parallel between the history of the Universe and its logical structure' (Weinberg [1977], p. 149).

In view of this, the idea of the possible evolution of the laws of nature in real historical time suggests itself quite naturally. Indeed, it appears as if no absolutely time-invariant entities exist in the physical world, while any stability and constancy may be only relative. The actual state of affairs seems to be quite in accord with the early reflections of Alfred North Whitehead, one of the founders of 'process philosophy':

> The modern evolutionary view of the physical Universe should conceive of the laws of nature as evolving concurrently with the things constituting the environment. Thus the conception of the Universe, as evolving subject to fixed, eternal laws regulating all behaviour should be abandoned (Whitehead [1933], p. 143).

However, any hope that the idea of an evolution of laws might demand a radical revision of a worldview perspective abates considerably as this general outlook assumes its distinct contours. And, after simple analytical examination, the idea of the evolution of laws is often qualified as utterly untenable, *inter alios* by philosophers (see, for instance, Butryn [1986]). The discussion of its specific aspects tends to reduce to redefinitions of basic concepts and refinement of their logical meaning. It is possible, for instance, to proceed from the logically consistent conviction that the laws cannot change *by definition*. It was argued also that the idea of evolution of laws is inconsistent with the deterministic explanation of nature (Augustynek [1967]), etc. It is due to this diversity of viewpoints that the necessity arises to set forth most precisely the frame of reference of the possible discussion, *i.e.* to elucidate *what* is actually the essence of the problem and *by what conceptual means* it has to be solved.

Much (if not everything) depends here upon the particular understanding of the status of natural laws. This latter theme has been thoroughly debated, but still there is no prevailing consensus as to what a law of nature is. Hence there exists a wide spectrum of views concerning the idea of natural laws' evolution. It is clear, therefore, that the notion of natural law cannot be used in a wholesale and unspecified way.

In the following I shall adhere to what may be called the *realist* account of natural laws, according to which the latter are *immanent* in nature as essential and at least relatively time-invariant links between its structural elements. The relation of natural laws and regularly occurring phenomena is moderately realistically (*i.e.* rather in an Aristotelian than in a Platonic spirit) interpreted as the relation of *general* and *particular*. The laws of *nature* actually 'live' in the natural world, its objects and processes as general in particular. The laws of science, on the contrary, 'live' in the ideal world of scientific knowledge and more or less adequately reproduce in some symbolic system various aspects of the *general* in the inherent structure of the real world.

On this assumption, my purpose will be to show that the idea of evolution of the laws of nature is *methodologically legitimate*. That is not to say that the laws of nature *do* evolve. Only that the *possibility* of their evolution is consistent with the realist worldview and a reasonable scientific methodology. For all that, we have to demarcate two subproblems: (1) what *reasons* may there be in favour of possible mutability of natural laws? (2) *by what means* can this possible mutability by conceptualized in scientific language? As we shall see, it is a matter of significance (*inter alia*) that the above questions be *posed* in the right *order*.

The foregoing account clears up the inner logic of the problem. It is better to approach its core, the most essential and the least examined aspects gradually, step by step. For that purpose it would be reasonable first to dwell briefly on rather simple and indubitable matters.

2 THE CHEMICAL CASE

In the first place, the problem of evolution of natural laws should not be substituted for the question of 'evolution' of scientific laws that signals the development of science itself. With the progress of science, a deepening synthesis of knowledge is accompanied with the formulating of more and more general laws of science. This evolution of knowledge apparently has nothing to do with the evolution of natural laws themselves. We cannot speak of the latter unless we are able to ascertain the mutability of common, 'invariant', essential connections and relations in nature in the course of some real natural process (*e.g.* the emergence or annihilation of these relations).

Such processes certainly occur. As an instance, the laws of chemical phenomena could not *come into existence* until the objects had been formed that were capable of interacting chemically. It happened obviously during the definite cosmic epoch when the temperature fell sufficiently to enable formation and stable existence of neutral atoms and then molecules of various substances. Prior to this epoch there were no chemical laws. Hence it is reasonable to speak of their coming into being at some stage in the cosmic evolution. Likewise, given the possibility of a closed cosmological model, in a few billion years the expansion of the Universe could be replaced by its contraction accompanied with the temperature increase. At first, molecules will dissociate into their constituent atoms and, later, atoms in turn will dissolve into nuclei and free electrons, and the chemical laws will cease to exist. Thus the laws that govern the behaviour of certain material structures cannot be pre-existent or postexistent with respect to the entire classes of such structures. In other words, the general starts and ceases to be relevant together with the particular.

Emergence and annihilation represent the degenerate version of evolution. It would be significant to examine the possibility of gradual change in the laws of nature (*e.g.* their evolutionary becoming or degradation).

3 THE BIOLOGICAL CASE

Let us consider the so-called 'evolution of evolution' effect (Kolchinskij [1987]) manifested in biological laws. It is quite natural to suggest that in the process of progressive biological evolution its factors and moving forces (*i.e.* heredity, population dynamics, reproductive ability, trophic relations, etc.) are subject to change no less than its products. The evolution of factors (as well as products) proceeds under the pressure of selection. There seem to exist different types of changes in the causal basis of evolution. Along with the appearance of qualitatively new factors and disappearance of the old ones ('degenerate' evolution of evolution), it is possible for them to join into a new composition or to change the intensity of operation gradually. The laws of nature, that is, the systems of essential relations, are embedded in the 'world of essences' that is subject to development as well as the 'world of phenomena'. That is why the persistence of laws cannot be absolute; it depends on the depth of the above-mentioned essences. Consequently, the biological evolutionary description in terms of essentially immutable laws may turn out to be inadequate. The more precise description must include a new dynamical dimension—an evolution of laws.

It is to be noted that in the 'biological case' we have to deal with the problem of *representation*: the mutability of laws must be properly incorporated into scientific language. (In the 'chemical case' there is no such descriptive problem). Irrespective of the technical details of this description, it is important that no *explicit* involvement of the time parameter in the structure of scientific laws is implied here. Evolutionary factors depend directly on the current state of affairs, while their temporal behaviour is a sort of *implicit* function. Given the 'initial conditions' of biological evolution along with all its potential factors and moving forces, it would be possible to unfold its exact scenario. And then one could derive from it the direct temporal dependence of factors and moving forces. But such a scenario would make the entire problem of 'evolution of evolution' superfluous. In fact, the 'initial conditions' are not known, and the same can be said of 'all potential factors'. It is clear, at the same time, that a sort of a 'feedback' between the structural aspects of a natural system and the laws of its development makes the whole system deterministic. That is why we must speak of *coevolution* of dynamical compound 'objects + factors and moving forces'.

At this point we can ask if the probable 'evolution of evolution' *modus operandi* in biology is a sufficient reason for general judgement favouring the changeability of natural laws.

4 DILEMMA OF REDUCTIONISM

Suppose that, as a result of some cosmic catastrophe (say, a collision with a large asteroid), the Earth lost a portion of its mass. The weight of all terrestrial bodies would be diminished perceptibly. Does this mean that the law of gravitation would have changed? Of course not. This law would remain the same, and what would have changed would be the result of its action in quite a wide (from the earthly point of view) but vanishingly small (in the large cosmic scale) realm of phenomena. This resultant 'law of terrestrial gravitation' is the sum total of a fundamental 'true' law and the particular disposition of basic objects (*i.e.* small fragments of earthly mass). The latter in general does not lie dormant, whereby the weight of bodies at the Earth's surface varies. But such variations occur against the background of constant fundamental law.

Consider, by analogy, the relation between two classes of natural laws: (a) the universal laws of 'higher' structural levels of reality which govern the behaviour of all objects on these levels (chemical, biological laws), and (b) fundamental physical laws. It is obvious that the answer to the question posed in the previous section is largely determined by the interpretation of the relation between (a) and (b). This is nothing other than the problem of reductionism. The main attitudes here are well known. Let us apply them to our case.

According to the *antireductionist* position (it is sometimes labelled also by the term *polyfundamentalism*), the laws of class (a) are *no less* fundamental than the laws of class (b) and can *by no means* be reduced to the latter. In particular, the operation of biological laws is not just a sum total of the operation of physical laws and certain dispositions of basic objects (particles and fields) constituent in every complex object including biological ones. But it comprises something else that cannot be comprehended in purely physical terms. In other words, the (a) laws are assumed to be *ontologically independent*. In that case the above examples of chemical and biological laws are in principle quite sufficient for a general assertion of the possibility of natural laws' evolution.

But the most methodologically interesting aspects of the problem come to light in the *reductionist* (*monofundamentalist*) context. It is now commonly agreed that the reductionist position is not to be identified with *naïve* reductionism (see *e.g.* Ayala [1983]). Unlike the latter, *methodological* reductionism does not question the qualitative novelties of a complex system with respect to its constituent elements. That the system is not an 'arithmetical sum' of elements is quite obvious. It is argued at the same time that the emergence of qualitatively new properties and law-like features of a complex structure can *in principle* be explained in terms of its elements' properties and their laws of interaction provided they are properly studied. It is claimed also that science must look for such explanations. To put it another way, the correct methodological strategy consists in a relentless search for more and more fundamental explanations. Such an approach has proved fruitful during the history of science since Newton and Galileo. The reduction of (a) laws to (b) laws is certainly a far more difficult problem than, for example, the unification of fundamental interactions (which is also a kind of reduction). This former problem is apparently unsolved and actually may be unsolvable by the available scientific means. But there are no *a priori* principles rendering such a reduction impossible in the near or far future. It is not necessary to demand the actual reduction even from future science. In practice, such a procedure may be unjustified in light of the attendant material and intellectual expenditures. It is sufficient, then, to prove theoretically the abstract possibility of this reduction. A relevant example: modern technology perhaps enables one to build an artificial mountain as high as Everest. But humanity would hardly involve itself in such an ambitious enterprise. The abstract possibility alone testifies to the actual standard of technology.[1]

Therefore, if we take up the position of methodological reductionism, then biological (and all other) laws are derivatives of the truly fundamental physical laws. And, therefore, the quite possible inconstancy of (a) laws does not suffice to assert possible mutability of natural laws as such. The evolution of biological or chemical laws can successfully proceed 'against the background' of constant fundamental laws. Taking this into account, we are prompted to ask *whether the fundamental laws of nature may change.*

5 THE CONCEPT OF FUNDAMENTALITY

This question demands some clarification. The concept of fundamentality is primarily associated with the laws of science, not the laws of nature. It concerns the most profound level of knowledge about nature. However, there is something in nature itself that corresponds to it, namely the most profound level of its *inherent structure*, mastered conceptually by science. At this level there exist specific objects, their (primary) qualities and properties described in the language of science by corresponding theoretical objects and their model characteristics. The necessary persistent relations between them are the fundamental laws of science. Real *referents* of the latter are none other than the fundamental laws of nature. Besides them, there is a whole hierarchy of 'secondary' natural laws. Their action consists partly of the action of laws of a more comprehensive level and partly of the particular arrangement of basic objects of that level. (Remember that our study proceeds within the reductionist framework.) The corresponding hierarchy of theoretical objects and relations between them (including universal ones, *i.e.* particular scientific laws) is partly interpreted in terms of observables and 'empirical laws'. It is clear that the predicate of fundamentality may be granted to some law only provisionally. The hierarchy of structures, mastered by science, is constantly growing up (or rather down) and, consequently, new relations of *reduction* are forming in the scientific description. For example, the laws of electroweak, strong and gravitational interactions are referred now to as fundamental. Tomorrow the situation may change, for

[1] I owe this example to Professor S. V. Illarionov.

the corresponding laws of nature are quite reasonably believed not to be ontologically independent. So further reduction of the aforementioned laws of science is to be expected. In current inquiry there is a great variety of proposals as to how this may be done, though a generally accepted and corroborated theory is still lacking. But what is important is that all the time the 'ground floor' of the hierarchy of laws is in view. By this we mean that the present 'most' fundamental natural laws are regarded as being ontologically independent, while the respective scientific laws are regarded as being irreducible to the more general ones until there is hard evidence to the contrary.

Therefore, the initial problem must now be stated more exactly, for it is senseless to inquire about the evolution of the laws of nature *in general*—each time the question must be posed anew. The evolution of any particular (*i.e.* 'secondary') law is also of no interest. As we have seen, it can proceed against the background of the immutable fundamental laws due to the rearrangement of the fundamental objects (*i.e.* basic objects of the fundamental structural level). The most essential question now may be of the evolution of the 'fundamental laws of nature' in the sense stated above. By 'fundamental' we imply the deepest level in the inherent structure of nature studied today and any time by current fundamental science.

6 POINCARÉ'S ARGUMENT

Such an approach to the problem, as well as a quite certain solution to it, were first proposed by Henri Poincaré in one of his famous last essays on the philosophy of science (Poincaré [1911])[2] written in a characteristic form of polemics with an imaginary opponent.

According to Poincaré, the essential *immutability* of the fundamental laws is a *necessary precondition* of the entire scientific enterprise. To deny the first is simply to undermine the second.

To state the fact of the evolution of laws, says Poincaré, it is necessary to get access to the remote ('geological') past; and to learn about the past one has to apply the essentially immutable laws linking past and present.

> If then the immutability of the laws plays a part in the premises of all our reasoning process, it is bound to occur in our conclusions (Poincaré [1963], p. 3).

In practice, any scientific judgement about the past state of the world results from extrapolation of the laws known today; and it is quite probable that the direct extrapolation of them might lead to nonsense. However, from this would follow not evolution of laws, but their inexactitude. If there is no

[2] Translated in Poincaré [1963]. Hereafter the references will be made to this edition.

other way to remove contradictions through experience or common sense, then it is possible in the last resort to assume the mutability of 'observable laws'. Such an 'observable law' is, however, the total result of the 'true', fundamental laws and a particular 'arrangement' of fundamental objects, the latter being inconstant and forcing the 'observable laws' to change. But the 'true' laws never change. Moreover, any supposition of variations in 'observable laws' can be articulated only on the basis of the principle of immutability of fundamental laws. This principle therefore can serve as a sort of pragmatic definition of fundamentality (Poincaré [1963], p. 13):

> No law will ever be relegated to the rank of being transitory, only to be replaced by another law more general and more comprehensive; that law will owe its disgrace merely to the advent of this new law so that there will have been no interregnum and the principles will remain intact; and it will be through these principles that the changes will be made and these very changes will seem to be an obvious confirmation of them.

This conclusion, as well as the arguments, of Poincaré reshape the problem of the evolution of laws in the most clear-cut and polemically acute form. But, as was noted, it is essential in discussing this problem to specify the exact meaning of the key terms. And, first of all, we must define the notions 'law of nature' and 'law of science'. To some extent such a semantic background is implicit in Poincaré's work. According to his way of thinking, what we call the laws of nature are in fact the laws of science. The notion of the law of nature as such is devoid of any clear-cut meaning. Still less sense is contained in the dispute as to whether the laws of nature themselves can change or are immutable. Poincaré notes ([1963], p. 13):

> Up to this point we did not seem to worry whether the laws really vary but only whether man can consider them variable. Are laws, considered as existing outside the mind that creates or observes them, unalterable *in themselves?* Not only is the question impossible of solution but it is meaningless. What is the use of wondering whether in the world of intrinsic things the laws can vary with time whereas in a similar world 'time' is perhaps meaningless? What this world consists of, we cannot say nor conjecture; we can only conjecture what it seems, or might seem to be to minds not too different from ours.

By no means can we say anything certain of the laws of nature *an sich.* So while discussing the evolution of the fundamental laws of nature, we imply, as a matter of fact, the time-dependence of the fundamental laws of science. And this latter problem is solved by Poincaré quite unambiguously: the fundamental laws of science are timeless by definition. In this respect Poincaré's conclusion is actually a methodological decision. The question, however, is, can this decision be considered final?

7 LAWS AND LANGUAGE GAMES

I strongly suspect that, even within Poincaré's methodological framework, the metaphysical context of discourse remains underspecified. It is to be accepted that the concept of a law of nature as such is empty as opposed to the law of science. The difficulty arises as soon as one attempts to name at least one law of nature 'of itself', apart from human conceptualization. Such an attempt is certainly doomed to failure, for to name something is at the same time to establish this something in language and thought, to incorporate it into a pre-existent grammatic and semantic structure. In this respect, all particular judgements about the laws of nature (their structure, mode of operation, etc.) are formulated solely in terms of the laws of science (*i.e.* by means of some language system). But the only judgement about the laws of nature that can and must be passed apart from and beyond any language is the judgement on their *existence* or *nonexistence* in the real world, 'out there', in the form of stable, recurrent and (at least relatively) constant links and relations.

In one *realistic* case not only the particular but also the *general* is believed to exist in reality. Then the knowledge of things and the knowledge of relations and links between them—including universal relations and links (*i.e.*, the laws of nature)—proceed essentially in one and the same manner. Things, as well as relations, are perceived by us indirectly, via their ideal reflection in mind. There can be no direct contact with them apart from the forms of human perception and thought. If we, in spite of this, do not question the real existence of things, then, according to the realist doctrine, there is no reason to doubt the immanent reality of natural laws. On this account, the problem of the possible evolution of fundamental laws as such makes sense, though it is far from trivial.

In the other, *nominalistic*, case this problem has no sense. The laws function in this case as the elements of a 'language game' in the course of which physical reality becomes intelligible[3] and assumes those formal 'contours' that render its conceptualization by means of scientific language possible. On these assumptions, it is to some extent quite natural to choose the 'rules' of the language game in the most convenient way. In particular, for the purpose of description, it is reasonable to consider the most fundamental of all known laws of science as immutable (by definition) and to adhere to this rule whenever even more fundamental laws appear in our description. It is possible to do so just because the laws of nature, being identical in this Wittgensteinian perspective to the laws of science, have their source, locus and rationale in *language* (not in nature), in its grammar and semantics, and these latter may be chosen and corrected largely conventionally.

[3] On the analogy between Wittgensteinian 'language games' and scientific enterprise, see Munitz [1986].

The rules of a nominalistic language scientific game are subject to more flexibility, the less credit is given to any inherent properties and relations (including the laws) in nature *an sich selbst*. But now it becomes clear that such a methodological decision (*i.e.* the decision concerning the 'rules of a game') requires as a necessary premise a more general *metaphysical decision* according to which nature as such is devoid of laws, regularities and any universals whatsoever. Does Poincaré make such a reservation? On the one hand, he seems to make it. In 'L'Evolution de Lois' he argues that

> the Bergsonian world has no laws; what can have laws is simply the more or less distorted image which the scientists make of it (Poincaré [1963], p. 14).

But in another place Poincaré maintains that the *relations* between phenomena are '*not less real* (italic added) than those which give their reality to external objects':

> These latter are real in this, that the sensations they make us feel appear to us as united to each other by I know not what indestructible cement and not by the hazard of a day. In the same way science reveals to us between phenomena other bonds finer but not less solid; these are threads so slender that they long remained unperceived, but once noticed there remains no way of not seeing them (Poincaré [1905], trans. in Poincaré [1929], p. 352).

The reference to 'cement' and 'threads' would be absolutely illegal in a consistent nominalistic interpretation of nature. For an explicit judgement is passed here on inherent properties of *Ding an sich* (namely on the existence of its coherent inner structure.) Poincaré himself seems to have hesitated in adopting any definite metaphysical decision on this matter or perhaps to have not attached importance to it. Such an attitude may certainly find some explanation. But, as has been shown, a consistent decision is quite necessary for an unambiguous interpretation of the general problem of laws' evolution.

Thus, at this point one more 'bifurcation' arises in our reasoning. (1) Either we adhere to the nominalistic attitude and suppose that there are no laws in nature itself while the alleged 'laws of nature' are in reality no more than the laws of science functioning as essential elements of the scientific 'language game'. In that case the initial problem may be solved conventionally. The most simple and convenient solution suggested by Poincaré is to consider the most fundamental (of all known) laws as immutable in principle. (2) Or we take on the (moderately) realist attitude and admit the existence of the general, not only the particular, in nature. Then this general may be the object of knowledge no less than the particular, and the question about some inherent properties of the former may be posed. Specifically, the problem of the evolution of natural laws makes sense and has to be solved, not conventionally, but essentially to the point.

Then (and only then) the order of questions is reversed: we have to argue not from the 'rules of the game' to the actual state of affairs, but vice versa. First, it is necessary to inquire whether there can be independent arguments favouring the possible mutability of fundamental laws of nature (*i.e.* real referents of the most fundamental, of all known, laws of science). Then, provided such arguments can be delivered, it is reasonable to investigate how the evolution of fundamental natural laws can be appropriately expressed by means of scientific language. In other words, the problem includes two aspects—ontological and epistemological.

What ontological reasons may there be in favour of a possible inconstancy of fundamental (in the sense stated above) laws of nature?

Let us remember the 'biological case'. In fact, it gives all the necessary arguments for a positive solution to this question in the *antireductionist* context. Provided the biological laws are as fundamental as the physical ones, the 'evolution of evolution' effect takes place: the continuous modification of 'fundamental' biological laws (evolutionary factors and moving forces) under the action of the evolutionary products themselves. But we have taken up a reductionist attitude. Now biological laws are not fundamental and their probable evolution might successfully proceed against the background of immutable truly fundamental laws by 'mere' rearrangement of fundamental objects—elementary particles and fields—constituent of all the other objects including biological ones. Could there be arguments for the mutability of the true fundamental laws of nature, similar to those of 'biological case'? I think there can be. To expound them, let us consider 'the cosmological case'.

8 THE COSMOLOGICAL CASE

Cosmology is rather specific with respect to the local physical theories of spatio-temporally restricted systems. The object of cosmology—the physical Universe—is unique in that it includes all that exists. The physical description of such a *totality* is supposed to differ considerably from that of a local system.

The overall description of the local system implies the specification of the law of its behaviour as well as the initial (boundary) conditions. The laws reflect common, persistent and reproducible features of phenomena and processes—*nomic* features. Initial and boundary conditions represent contingent, individual and, generally speaking, irreproducible instances of the laws' action. (More generally, it is possible to speak in this connection of all *factual* features of the system.) These latter features are to a considerable degree forced upon a system by its prehistory and surroundings. And, what is more, all these particular instances of laws in the infinite variety of systems with all possible initial and boundary conditions are assumed (most often implicitly) to exist actually or, at least, potentially (see Bondi [1948]). In any case, it is possible to demarcate the strictly nomic and factual features of a system and, respectively, *nomological* and *factological* elements in the description of the system.

To what extent do these assumptions apply to cosmology? There is only one Universe, and its evolution is perhaps the unique cosmic event. It is hardly possible to speak of common trends in behaviour since we have before us one and the only precedent. In any case this 'precedent' cannot be considered as one particular 'instance' of the laws of nature. With equal success may the latter be reputed as the consequence of the Universe's very existence. The laws of nature in no sense 'precede' the Universe. For the Universe as a whole, any clear-cut distinction between individual and universal, factual and nomic is vanishing.

All that can be said, in this respect, of the unique Universe remains valid also for any of the 'multiple universes' sometimes discussed in 'many-worlds', or 'world-ensemble', cosmologies (see, for instance, Leslie [1989]), since any such universe is supposed to be endowed with its specific physical constitution and causally disjoined from adjacent universes. Otherwise there would be absolutely no need to speak of 'multiple universes'. For that reason, the term 'Universe' will refer hereafter to either the unique Universe or to one of the 'multiple universes'. Bearing this in mind, we can conclude, in general, that the present structure of the Universe is produced not only by dynamical laws of evolution but also by its initial conditions. And so, the problem of their origin arises: why were the initial conditions just those, which have led to the cosmological picture observed today, and not others? It is not so clear whether the origin of universal initial conditions is of strictly factual or partly of a nomic character as well. Consequently, in the physical description of the Universe the epistemic priority of nomological elements over factological ones may loosen.

In practice, this manifests itself in a peculiar descriptive situation, when the cosmological implications of the local laws are in a sense given equal rights with their general formulation, since these implications determine just that unique world model which must conform to the actual Universe. On this assumption, the cosmological considerations can in principle become a sufficient reason for the modification of the general formulation of universal laws. Similar reasons impelled Einstein to modify in 1917 the general formulation of gravitational field theory to satisfy Mach's principle and the requirements of a static Universe model, the only one regarded then to be realistic. Quite analogous ideas resulted later in the 'perfect cosmological principle' and the steady-state Universe: to ensure universal validity of local physical laws, Hermann Bondi and Thomas Gold postulated immutability of the large-scale structure of the Universe and sacrificed the conservation laws for that.

In fact, what is responsible for such eccentric procedures? The point is that in a cosmological perspective the laws of nature are *coextensive* with the system determined by them. Indeed, not only the structural elements of matter, but also the *laws* of their interaction, not only factual, but also nomic aspects of reality, are 'located' in the 'territory' of the evolutionary cosmos (whether it be the unique Universe, or just one of 'multiple universes' governed by its specific laws). And what is more, the former 'covers' this territory entirely. That is why, from the point of view of present-day cosmology, nothing absolutely constant seems to exist in the world. We can speak with certainty of only more or less stable qualities and relations united with their variable counterparts in a complex network of interdependences. Not only are the substrate properties of the Universe subject to particular laws of evolution. The laws themselves may depend on the results of their own action, that is on the particular physical state the Universe happens to be in as it undergoes its evolutionary development. Physical laws are 'accommodated' completely on the territory of a changing, all-inclusive Universe, just as the laws of biological evolution are 'accommodated' completely on the 'territory' of a no less unique system, the biosphere. In view of this, physics, contemplating local laws in a changing Universe, must make, as Bondi rightly stressed, 'definite assumptions about the effect of these changes on the laws of physics. Even the statement that there are no such effects is evidently an assumption, in fact a highly arbitrary assumption' (Bondi [1957], p. 197).

Actually, the global character of particular (and factual, generally speaking) physical parameters fixing the state of the Universe is comparable to the universality of the laws of nature. The *loci* of all the laws, including the 'most fundamental ones', are in objects, linkages and relations of the Universe, and for that reason the laws cannot be isolated from the influence of the universal physical structure (*e.g.* of the matter density, temperature, large-scale velocity distribution). But the global properties of the Universe undergo radical reorganization, especially during the first microseconds of cosmic evolution. In such circumstances nothing can guarantee the stability of even the most intrinsic relations naturally built-in in the coextensive 'world of phenomena'. Thanks to this, any nomic feature may become a function of evolutionary process. For example, the (formally) nomic property of our world manifested in the spontaneously broken symmetry between fundamental interactions is perhaps due to the real process (of this symmetry's breaking) that occurred in the remote past as a result of the phase transition, the immediate physical cause of the latter being the fall of temperature, a quite 'factual' feature of the cosmic substratum.

The idea of a genesis and becoming of fundamental physical laws in the course of evolution looks therefore quite verisimilar. The possibility of 'self-transcendence' of even the most basic qualities and relations in the extreme physical conditions of the early Universe is to be reckoned with.

9 POINCARÉ PRINCIPLE

But the impossibility of survival of the *real* properties and relations of nature in the extreme conditions is only a part of the problem. The other part concerns the *reproduction* of these effects in scientific language. Though there can be in fact nothing absolutely constant in nature, our description of a changing nature is always in a certain sense absolutely *static* (namely in the same sense in which the 'text' of this description is static). By what conceptual means can the independently discovered evolution of the most fundamental laws of nature be reproduced in the system of knowledge?

One possible way to such a description immediately suggests itself: we must merely reinterpret Poincaré's arguments in an unambiguously realist conceptual context (though Poincaré himself would hardly agree with such a trick). It is possible to reason as follows. The development of nature, including its laws, is a process that proceeds, perhaps, on all structural levels. At the same time, the development of science is basically a step-by-step process. At any stage we deal only with the finite number of levels in the structural-functional arrangement of nature. Suppose we are able by available scientific means to build up a theoretical model of nature on all its levels up to *n* (inclusive). Now suppose that in the light of, say, ontological reasons proposed in the previous section, the inconstancy of the laws of nature at the level *n* has become apparent. So far, the corresponding fundamental laws of science of the level *n* had been considered constant. Now the inadequacy of such a description has to be admitted. How should we improve it by taking into account the actual mutability of the fundamental laws of nature of the level *n*?

Imagine a disciple of Poincaré who confesses, at the same time, the *immanence* of natural laws. It would be reasonable to assume that this hypothetical investigator should act according to the following maxim which can be dubbed 'Poincaré Principle':[4]

The constancy of laws in the description of nature may always be saved by the transition to a deeper level of fundamentality. Though no fundamental law of nature is insured against possible mutability, actual discovery of the latter cannot be considered 'ratified' unless a more general law of science is 'ready' that regulates the evolution of the former law while being itself immutable. The former law loses thereby its fundamental status.

As far as the aforementioned example is concerned, Poincaré Principle (PP) requires formulation of a new fundamental scientific law of the level $n + 1$ to describe the mutability of an ex-fundamental law of nature of the level n.

[4] I quite understand that Poincaré would most probably object to the combination of his arguments with a consistent realist worldview. So this hybrid intellectual device—the realist-minded disciple of Poincaré's methodology—is intended here only as a convenient means of reasoning.

The supposed force of PP is in its claimed *apodictical* validity, which can be violated under no circumstances. PP demands that the transition to a deeper level of fundamentality should be always realizable, and that, besides, (a) the new description should actually represent the law of nature of a deeper level, and (b) there could be no 'interregnum'.

In Poincaré's terms this latter condition is specified as follows:

> it will not ever happen that we shall observe variations of laws either empirically or inductively, nor shall we explain them after their occurrence by trying to fit everything in a more or less artificial synthesis. No, the synthesis will come first, and if we allow any variations, the purpose will be to prevent disturbing it (Poincaré [1963], p. 13).

The crucial problem is whether it is possible to ensure the apodictical validity of PP, while at the same time following the lines of the realist concept of natural laws. I shall try to show that it is impossible in the sense that, from the realist point of view, violation of both (a) and (b) is permissible and does not contradict any *normae* of science. In other words, I consider the situation in which the constancy of the most fundamental laws of nature turned out to be 'compromised' by sufficiently serious reasons, while a new law that would restore the constancy on a deeper level *is not identified* as a constant one (which would mean violation of (b)) and, perhaps, *does not at all exist* in the capacity of a constant (which would mean violation of (a)), as *methodologically legitimate.*

10 EVIDENCE OF 'INTERREGNUM'

The condition (b) in the form implied by Poincaré may in principle be violated in the realist context. In fact, let us suppose that empirical arguments appeared in favour of changes in the intensity of the universal gravitational force. These can be, for instance, either the direct radiolocation data of the deviation of lunar orbit, or the indirect geophysical or astrophysical effects in which gravity is of crucial importance. The evolution of the law of gravitation would not, of course, follow from these data with certainty. It would be rather just one possible interpretation of them. But it is essential that such an interpretation is in principle possible and does not require any preliminary formulation of new, more general laws. The problem situation that might result from these data would have a clear-cut empirical meaning. Some scholars would speak of the hypothetical variation of Newtonian gravitational constant. In this respect the 'interregnum' is at least logically possible; consequently, the (b) condition is not apodictically necessary.

It is quite another matter that the observation of such effects, especially taking into account their independent corroboration, would lead to confusion in the scientific community and stimulate the search for explanations. In fact, quite a similar situation arose once in the modern history of physics. In 1937 Paul Dirac proposed a hypothetical explanation of the wonderful coincidences of 'large numbers', the dimensionless combinations of some fundamental constants and the cosmological parameters that are responsible for the global properties of the Universe as a whole. These are the ratio of electromagnetic and gravitational interactions of, say, proton and electron. $N_1 = e^2/Gm_e m_p \sim 10^{40}$, the number of nucleons in the observable Universe, $N_2 \sim 10^{80}$, the age of the Universe, $t_U \sim 10^{10}$ years, expressed in atomic time-scale $t_a = e^2/m_e c^3$, $N_3 = t_U/t_a \sim 10^{40}$, etc. Dirac [1937] assumed that these coincidences cannot be accidental but are instead exact equalities, which must be explained in some future theory. According to the Large Numbers hypothesis, any dimensionless combination of fundamental physical and cosmological parameters of the order $(10^{40})^n$ must be equal to N_3^n. As a consequence, from $N_1 = N_3$ it follows that a Newtonian constant G must vary with a cosmological epoch: $G \sim 1/t_U$. In particular, for the present epoch the relative decrease rate of G is:

$$\dot{G}/G = -1/t_U \sim 10^{10}\,\text{year}^{-1}. \qquad (1)$$

Dirac's ideas were developed since then by P. Jordan, E. Teller and G. Gamow, among others. Thus, just the coincidence of natural constants, not their empirical inconstancy, induced the need for an explanation, and the Large Numbers hypothesis became one possible explanation in which the variation of constants was postulated. It would be difficult to overestimate the reaction that a probable observational discovery of such a variation might produce.

Nevertheless, let us try to imagine that such a discovery actually occurred. It can be stated for certain that a lot of explanations would be immediately proposed. And those in accordance with PP would of course prevail among them. In all PP-oriented explanations, new time-invariant relations would be introduced that should regulate variation of the (ex-)fundamental laws of nature. The condition (a) implies that these new relations must actually be the *laws* of science, which mirror natural order on a deeper level than the former, 'compromised' laws. The question now is, will it always be possible to satisfy this requirement?

II NOMIC-FACTUAL COEVOLUTION NETWORK

It may be argued that the confidence of a realistically oriented proponent of PP in its apodictical ability to satisfy this requirement (and also the condition (b)) would be largely based on the two considerations formulated (however, most probably in the nominalistic context) by Poincaré. First, on the 'molecular analogy':

> Let us suppose that observable laws are nothing but resultants, dependent both on the molecular laws and on the arrangement of the molecules. When scientific progress has familiarized us with this dependence, we will no doubt be able to infer that, precisely by virtue of the molecular laws, the arrangement of the molecules must once have been different from that of today, and consequently that the observable laws were not always the same. We would therefore conclude that the laws are variable, but we must note carefully that this would be by virtue of the principle of their immutability. We would assert that the apparent laws have changed, but only because the molecular laws which we have regarded formerly as the true laws were considered unalterable (Poincaré [1963], p. 12).

Implied in this analogy is the 'subordination postulate', according to which the laws of any level ('observable laws') are influenced by the underlying laws only ('molecular laws') and, generally speaking, the arrangement of basic objects ('molecules') of the underlying levels.

Secondly, the preservation of the immutability of fundamental laws in all circumstances becomes, according to Poincaré, rather trivial, provided the 'interpolation technique' is applied. Let the 'observable laws' in fact change. In that case they are described, say, by two different formulae during two observable epochs. Then an intellect, sufficiently powerful and lasting,

> will be able to complete the synthesis and to combine in a single and perfectly coherent formula the two fragmentary and related formulae which the two ephemeral researchers had reached in the short time they had at their disposal. To this intellect, the laws will not have changed, science will be unalterable; the scientists will merely have been imperfectly informed (Poincaré [1963], pp. 13–14).

The 'interpolation' must be understood here in the broad sense. In practice, it can manifest itself in new 'universal forces', the appropriate incorporation of which into the structure of scientific laws can be aimed at preserving their constancy in whatever circumstances. In this respect, the disciple of PP would have a wide spectrum of conceptual tools at his disposal to defend his position. He could propose at once several variants of 'universal forces'. Phenomenologically, one such variant might be no worse than another provided it describes equally well all known facts, for there is actually an infinite number of ways to conjoin smoothly two fragments of different curves.

But however convincing these two arguments ('molecular' and 'interpolational' analogies) might seem within Poincaré's framework, I argue that the appeal to them within the realist framework may turn out to be incorrect. The point is that a thereby modified law of science is very likely not to reflect any more actual law of nature. A natural law is not identical to a mere phenomenological link between, say, past and future. It is also a structural mechanism that includes intrinsic relations. That is why the modification of fundamental laws of science cannot be carried our arbitrarily. The status of such a procedure depends critically on whether the new 'universal forces' originate in a real physical source or are purely fictitious, intended solely for salvation of the immutability of corresponding scientific laws. That is not to say that the universal forces will always be fictitious, only that they can turn out to be fictitious provided their introduction is due solely for the purpose of preserving the immutability of laws. PP is not immune from the introduction of fictitious universal forces and, therefore, a trivial interpolation strategy does not ensure the appearance of more fundamental laws of science.

These arguments become quite clear in the cases to which the 'molecular analogy' does not apply. It happens any time the 'subordination postulate' is violated, that is, when the *inverse* effect of 'molecular arrangement' on the 'molecular laws' themselves takes place. As we have seen, this occurs, for instance, in the process of cosmological evolution because the laws of nature are, from a cosmological point of view, coextensive with the Universe as a whole (or its domain large enough to include all observable cosmos). As a consequence, nomic and factual features of nature unite in a single coevolution networking, a key example being symmetry-breaking due to the early phase transition triggered by a temperature drop in the course of cosmological expansion.

The influence of global properties of the Universe on the local laws is valid only within the realist framework. In the nominalistic perspective, where the laws are grammatic and syntactic, rather than ontological, bonds, such an influence would be quite inappropriate. However, this 'feedback' was clearly not foreseen in Poincaré's arguments either. It would apparently be an extra and absolutely unnecessary element therein. Hence, the rash application of an 'interpolation technique' (*i.e.* the introduction of new 'universal forces' for the salvation of scientific laws' timelessness) to the 'cosmological case' may sooner or later result in a false explanation just because the possibility of an inverse influence of changing global properties of the Universe on the local natural laws might deliberately not be taken into account here. At this stage the perpetually modified laws of science would stop to conform to the real natural regularities, and the application of PP would lead to no explanation but only to a phenomenological description concealing the above-mentioned intrinsic 'feedback' relations in the same sense as the geochronometrical conventionalism conceals the intrinsic relation of geometry and gravitation.

To illustrate these rather abstract ideas let us turn again to Dirac's Large Numbers hypothesis. Since it questions the time-invariance of the fundamental physical laws of gravitation, PP's proponent may be supposed to interpret it in terms of universal forces, the global factors intended to save the immutablity of scientific laws by entering into their structure. Now, *immutable* would be the *mathematical relation* of large numbers with each other and hence with cosmological epoch; so the time-drift of some 'constants' would be regulated by these timeless relations. And the best candidate for the role of 'universal force' would be the age of the Universe itself—the global changing factor, inherent in all empirical situations. But it is to be noted that the time-dependence of large numbers was postulated by Dirac in a purely phenomenological manner, without specifying its mechanism. It is obvious that such a mechanism cannot be identified with some direct 'influence' of time on physical laws. The role of real agent may be claimed here only by some sort of 'clocks', that is, some global physical processes expressing the flow of time in terms of a universal variation of substrate features. In this respect, Dirac's hypothesis is incomplete, and attempts to add a physical (not only mathematical) meaning to the time-dependence of large numbers in the form of, say, Mach's principle (Brans and Dicke [1961]) always result in *implicit* temporal dependence of corresponding 'constants' hidden behind their *explicit* dependence on matter density, velocity distribution and other real physical factors.

The point of this example at least is that one cannot save the immutability of scientific laws in a pure conventionalist manner, since then one can get an improper result corresponding to no real natural regularities. The crucial matter is the origin of universal forces. In one case, they are due to a certain real (let it be hypothetical) physical source. In another case, they are essentially fictitious. Phenomenologically, these two cases may be indistinguishable. In our example, the original Dirac hypothesis as well as the Brans–Dicke theory describe equally well the known facts (*i.e.* the present coincidences of some large numbers). But as far as a physical explanation is concerned, they are far from being identical and as a consequence predict, generally speaking, different relative rates of time-variation of Newtonian 'constant'. In the Dirac hypothesis this rate is given by formula (1). In one of the cosmological models based on Brans–Dicke theory of gravitation it is given by (Narlikar [1983]):

$$\dot{G}/G = -(2/(3\omega + 4))\cdot 1/t_U, \tag{2}$$

ω being a coupling-constant of a scalar field.

Therefore, the description of the evolution of the (formerly fundamental) law of nature of, say, level n by the essentially invariant (now fundamental) scientific law of the level $n + 1$ may turn out to be a rather non-trivial problem, provided the laws of science are regarded as being the reflection of real natural regularities, and not only grammatic and syntactic rules of the language game in the course of which reality becomes conceptually transparent. A realistically oriented PP's proponent in examining the 'cosmological case' must admit that (1) the 'interregnum' is possible and hence that it is necessary to drop the condition (b); (2) global properties and relations of nature on levels from 1 to n may impose an 'inverse' influence on natural laws of the level $n + 1$ and below. So the 'subordination postulate', implicit in PP, may be violated and the simple 'molecular analogy' can stop working.

The gist of the whole business is then concentrated in the question: would it be possible to find a solution (let it be non-trivial) to this descriptive problem within the realist framework and, at the same time, if not in the letter, then at least in the spirit of PP? That is, can at least sophisticated PP, released in the light of (1) and (2) from apparently excessive requirements, be considered apodictically valid?

12 SOPHISTICATED PP DEFENDED

A more subtle examination shows that, in the above example of symmetry-breaking associated with cosmological phase transition, the sophisticated PP demonstrates its fruitfulness. The point is that behind the broken symmetry a more fundamental (hidden) symmetry is supposed to stand. We live in a low-energy epoch ($T \sim 3°$K) with broken symmetry. Because of this, a photon, say, is massless whereas the masses of $W^{\pm}$ and Z^0-bosons are not zero. But all this must not lead anyone astray. One has only to warm up the cosmic substratum to approximately 10^2 GeV (*i.e.* 10^{15} K), and the broken symmetry will be restored, and the masses of all bosons will vanish. In the history of the Universe the inverse process actually occurs. However, it has to be treated not as modification of the most fundamental laws of nature, but rather as the spontaneous appearance of a new structure (namely the asymmetric vacuum) from already present, more fundamental 'material'. By 'structure' I mean here, of course, not some regularity in the usual space, but a system of intrinsic relations in the 'space' of quantized fields. Nevertheless, in the essential sense, the creation of such a 'structure' is quite similar to the 'appearance' of chemical laws at some stage of universal evolution, the role of a 'trigger' being played in both cases by the global decrease of temperature. As we have seen, in the 'chemical case', PP is valid even in its original form. But in the case of a broken symmetry it is also valid in its sophisticated version. The sophistication consists in the violation of the 'subordination postulate' (and hence the inadequacy of a simple 'molecular analogy') due to the influence of a macroscopic feature, the temperature, on the working of fundamental physical laws. But it is this influence that accomplished a transition to the new level of fundamentality in our description. On this particular level, the dependence of the form of the Higgs field's potential on energy (*i.e.* cosmologically speaking, on temperature of cosmic epoch) is given. It is the peculiarities of this potential that determine the dynamics of symmetry-breaking (see Linde [1990]). The form of potential varies with energy conditions, but its dependence on temperature remains the same. And this dependence certainly reflects physical reality on a deeper level. Because of this, the fundamental laws of interactions depend explicitly on temperature and develop thereby in coevolution with matter. The most adequate conceptual tool to describe this unique regime of coevolution is a cosmological scenario. From this scenario, as a consequence, the implicit temporal history of laws can be deduced. It is possible, in particular, to pin down the moment of symmetry-breaking phase transition in the temporal scale of evolution. But there are more fundamental and immutable (more exactly, at least presently supposed immutable) laws standing (to crown the satisfaction of PP's proponent) behind this dependence.

The matter is somewhat different in the case of a gradual variation of the gravitational interaction in the cosmological implications of the Brans–Dicke theory mentioned above. In view of the violation of the 'subordination postulate', the dependence of the Newtonian 'constant' on time, as we have stated, is also implicit, 'hidden' behind its explicit dependence on changing global properties of the Universe (*i.e.* density and distribution of matter). But this latter dependence is nothing else than that more comprehensive and (at least for the present time) immutable law which saves the (sophisticated) PP. To refine this assertion, the Newtonian 'constant' is no more constant, and with it other properties and values lose their fundamental status. But as this happens, at the same moment new, stable, fundamental values appear, such as the coupling-constant ω (see formula (2)) and hence the new and more compehensive level of description. In this particular cosmological scenario, the dependence of the former fundamental nomic values on the global but factual properties of the Universe turns out to be immersed into the 'time-flow'. But this dependence does not change its form with evolution (more exactly, it is supposed in this theory to be unchangeable). It is not difficult to see here an analogy with the 'biological case' viewed from a reductionist standpoint: the evolution of 'observable' laws occurs 'against the background' of the 'true' laws via rearrangement of basic objects. In the 'biological case' these latter are the objects of a much deeper level (physical particles and fields) joining into 'biological combinations'; whereas in the 'cosmological case', in virtue of violation of 'subordination', these are the objects of the same level (*i.e.*, the elements of the physical structure of matter), at which the variation of natural laws is manifested. Therefore, the sophisticated PP works in this situation as well.

What are the roots of its exceptional tenacity? I think they are in the universal applicability of a hierarchical, layer-upon-layer model of reality and its natural counterpart, the universal 'covering-law' explanatory structure.

The *explanans* of such a structure is usually a conjunction of a law of science and some factual parameters that specify the particular case of the law's application. The *explanandum* can be either some factual state of affairs in the real world or some 'secondary' law of nature. Due to the overall hierarchical structure of physical reality (which is not necessarily to be subject to direct geometrical representation), any particular law of nature as well as the realm of its validity are explained in the local physics by the more general law, the relation between these two laws being supposed to exist in 'synchronous' perspective and to be reproduced by logical relations. In cosmology, such an explanation is also possible, but it necessarily assumes the additional 'diachronic' meaning. The task of such a cosmologically rooted covering-law explanation may include rather non-trivial (from a local viewpoint) matters, namely the *genesis* of some particular law from 'non-being' or 'other-being'. For example, separate electromagnetic and weak interactions, together with their intrinsic laws, originate in the evolutionary trend from the united electroweak interactions. And since the reality, 'carrying' the laws (and coextensive to them), also modifies, the 'feedback' relations, violating the 'subordination', can appear between the layers of reality's structure. But, as was shown, the identification of such feedback linkages is accompanied each time by a transition to the new, more comprehensive description, and by an introduction of the new 'covering' law, extending the phenomenal domain 'covered' by laws.

It is unimportant that the whole hierarchy of natural structures may find itself immersed in the 'time-flow'. This does not invalidate the former, static model of explanation. In virtue of hierarchism, at each stage of penetration into reality it is possible to call up even more comprehensive 'covering' relations, to bring them (let it be just for a time, not forever) out of the evolutionary context and to separate admittedly variable relations into the 'covered' part. This operation can be repeated infinitely; each time the portrait of evolving reality will be, of course, approximate, but the adequacy of the entire approach is undoubted, since the iterative character of knowledge conforms very well to the hierarchical world-structure.[5]

It must be admitted that this standard explanatory pattern works very well in the sciences and, among others, in evolutionary disciplines such as biology and cosmology. And there are no reasons to consider its potentialities exhausted or even restricted. Therefore, the sophisticated PP is assertedly valid in the sense that all practically known modes of description of evolving systems are quite compatible with it. But the question is of the apodictical validity of this principle. That was the approach of Poincaré himself in his polemics with E. Boutroux and other proponents of the accidental character of laws. Apodicticity means that the violation of PP would lead to the undermining of the basis of science, no less. PP would function in this case as an '*a priori* form of scientific reason'. Its validity would be a necessary condition for the possibility, and even the conceivability, of a scientific

[5] It is to be emphasized once more that this hierarchy must not be identified with some visually representable pyramid. It can be any system endowed with intrinsic relations that might be subject to some sort of ranking, allowing one thus to speak of the levels of organization.

description of changing nature. Only having passed through the PP's prism would reality assume the formal cutouts conducive to scientific conceptualization.

I think that such a categorical statement of PP's apodictical infallibility would be, however, unsubstantiated. Moreover, it is impossible to substantiate it once and for all within the realist framework where, paraphrasing Wittgenstein, 'the forms for discussing reality', are derivatives of the 'forms of reality itself' (*i.e.* ontological ideas). And since the latter may change and in a quite radical and unpredictable manner, as the history of science testifies, there can be no guarantee that in any such change of ontological views of the 'forms of reality' would it be possible to retain intact the 'forms of its discussion'.

Consequently, while various cases of sophisticated PP's successful working convince us of its assertive force, that does not prove its apodictical validity. Conversely, were it possible to show that within some logically consistent model of reality the sophisticated PP breaks down in one (let it be even the most 'marginal') case only, it would be sufficient to proclaim the apodictical fallibility of PP.

13 THE TELLING CASE: BOOTSTRAPPED UNIVERSE

Taking this into account, let us formulate the last thesis to be substantiated:

The condition (a), and, consequently, even the sophisticated PP, may be violated, provided there is immersed into the 'flow of time', not the hierarchical, but the bootstrap-like structure.

The bootstrap model of reality is rather peculiar in that it questions the most natural and undoubted views on the structure of physical world (Cushing [1985], [1990]). It is supposed in this model that on some level n of the structural organization of nature the principle of *hierarchy* stops being valid, and instead of it the principle of *self-consistency* comes into force. All basic objects of the level n are no longer assumed to consist of even more elementary objects of the level $n + 1$, for example. They are considered instead to consist of all other objects of the same level n. The set of these truly fundamental entities is given in terms of 'mirror' relations between them (Gale [1974]). The self-consistency requirement completes such a system: all extra degrees of freedom vanish, and all *a priori* contingent features become factually, as well as nomically, necessary. The totality of these fundamental elements form one indivisible whole. Hence the specification of one of them gives, at the same time, via 'mirror' inherent interrelations, the whole spectrum of all the others.

George Gale [1974] is quite right when he notes that the world based on such an ontology cannot be created in parts, step by step. It can only emerge simultaneously, as one indivisible whole. But what prevents the already created-by-the-bootstrap Universe from global evolution under strict supervision of the self-consistency principle? The mirror interrelations would be subject to deformation during this evolution, whereby the properties of elements and their linkages would also change. But the proponent of sophisticated PP, in order to save the constancy of laws, would have no ontological reasons to perform a transition to a new level of fundamentality due to the absence of the latter. The hierarchical structure of reality would cut on the level *n*, and there would exist no deeper connections and relations responsible for the state of affairs on this 'limit' level. It would be a self-contained complex of nomic and factual features. The description of the coevolution of them would not imply the introduction of the more fundamental connections and relations in the hierarchical sense.

However, provided one does not insist on this trivial meaning of the term 'more fundamental', it is quite possible to treat the principle of self-consistency (that reflects the essence of mirror interrelations of basic objects on the level *n*) as the more fundamental mode of description compared with the reduction of one hierarchical level to another. Then it is necessary to inquire whether the description of evolution of a bootstrap Universe in this more fundamental self-consistency *modus operandi* would satisfy the sophisticated PP. For this, let us consider the cases of 'continuous' and 'punctuated' evolution.

In the first case the 'gradual' deformation of mirror interrelations between basic elements of the bootstrap Universe takes place. However, the self-consistency principle would most probably express the essence of these interrelations in time-invariant form, in terms of constant functional interdependence of changing quantitatively, but retaining their qualitative identity, features. The invariance of these functions would be equivalent to the presence of the more comprehensive description. In view of this, the picture of the continuous deformation of bootstrap relations would almost certainly be compatible with the requirements of sophisticated PP (provided the term 'fundamentality' is not interpreted too narrow-mindedly).

Now suppose the gradual evolution of the bootstrap Universe is interrupted at some moment by a sort of 'phase transition' accompanied by sharp qualitative rearrangement of the structure of mirror relations between basic elements. In that case the two fragments of evolution separated by a 'phase transition' must be described by two different and irreducible functional interdependences, since at the moment of 'phase transition' one form of self-consistency is substituted by another qualitatively different form of self-consistency. And unlike the standard cosmological phase transition with symmetry breaking in the unified gauge theories, nothing similar to the more fundamental, 'hidden' symmetry, 'standing behind' the broken one, exists in the bootstrap case. In fact, the bootstrap ontology does not allow one to prop up the level n in our description with a deeper level $n + 1$. Both forms of self-consistency represent mirror interrelations of elements on the limit level of elementarity. And so any attempt to unite these two different forms of self-consistency in one, say, 'interpolation formula', would be ontologically groundless. It would be virtually identical to the deliberate introduction of fictitious 'universal forces'. Consequently, the situation must be taken at its face value, and a realistic scenario of the entire history of bootstrap world as a whole must include the two ontologically and hence descriptionally irreducible 'aeons' connected with each other only by their temporal succession. By no means must we imply the anarchy in the behaviour of the system itself. The coevolution—the mutual dependence of the evolutionary changes of nomic and factual properties—would make the system deterministic during both halves of its history. And the moment of 'phase transition' would be strictly caused by the preceding evolution.

Bootstrap ontology is now in opposition and exerts almost no influence on modern physics. But it is quite compatible with reasonable scientific methodology. Moreover, one can remember that it was once a viable alternative to the standard quantum-field approach to strong interactions (see Cushing [1990]). So the arguments based on bootstrap ontology are at least methodologically legitimate. Given the logical possibility of a scenario of 'punctuated' evolution of the bootstrapped Universe, these arguments demonstrate the apodictical fallibility of even the sophisticated PP.

14 CONCLUSION

It might be argued that the mountain has brought forth a mouse, since our mighty efforts of critical examination of PP have produced rather insignificant results, especially in view of the present practical uselessness of a bootstrap ontology. In reply to this probable remark, I would make just two comments. First, it is not at all obvious that a deeply convinced PP's proponent would remain untouched by the arguments proposed in this paper. Second, it was my purpose from the very beginning to develop a consistent realist account of the problem of natural laws' evolution. As was emphasized in the introductory remarks, this problem is a classical example requiring a step-by-step approach. I would like to think that in this way some clarification of rather controversial issues concerning the status of natural laws has been achieved within the realist framework. And it is pairticularly important that at some stage these issues become deeply connected with cosmological questions.[6]

Department of Philosophy
Moscow Institute of Physics and Technology
Institutsky per. 9, Dolgoprudny
Moscow Region 141700, Russia

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