**A SIMPLE THEORY-CHANGE MODEL.**

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**Abstract.** A comprehensible model is proposed aimed at an analysis of the reasons for theory change in science. According to model the origins of scientific revolutions lie not in a clash of fundamental theories with facts, but of “old” fundamental theories with each other, leading to contradictions that can only be eliminated in a more general theory. The model is illustrated with reference to physics in the early 20th century, the three “old” theories in this case being Maxwellian electrodynamics, statistical mechanics and thermodynamics. Modern example, referring to general relativity and quantum field theory, is considered.

**Key words:** Popper, Kuhn, Stepin, Einstein

**INTRODUCTION.**

 What are the reasons for theory change in science? According to the well-known account, any theory-change process takes place as a result of a critical experiment (Popper). The experiment reveals the old theory’s inadequacy, which manifests itself as either a contradiction of the critical experiment, or as a tendency to adapt to its results using auxiliary ad hoc hypotheses. However, in fact the widely accepted “critical experiment” model or concept is based on the so-called “standard” hypothetico-deductive interpretation of the scientific theory. Those who uphold this interpretation maintain that all the scientific theories are structurally remarkably similar to the interpreted calculi of axiomatic theories of mathematics. This means that any scientific theory can be reconstructed so that its content may be logically deduced from a certain number of initial hypotheses. In this case, the refutation of any single result automatically represents the refutation of the initial hypotheses and, consequently, of the whole theory. One single critical experiment is sufficient to refute any theory. Today the majority of philosophers of science argue that standard hypothetico-deductive interpretation of scientific theory is insufficient. This interpretation cannot adequately grasp the whole group of scientific theories, as these theories obviously contradict accepted standard interpretation of canonical axiomatic reconstruction. The Standard Interpretation has been replaced by a so-called “nonstandard” one. The latter has yet to be fully defined, and its advocates differ significantly in their views. They share the following ideas. Any scientific theory contains at least three groups of hypotheses that differ from each other in their functions:

(1) The mathematical hypotheses form the mathematical apparatus of the scientific theory. (2) The semantical hypotheses shape the scientific theory models (3) The fundamental hypotheses are the basic suppositions of the scientific theory. Besides the third group of hypotheses, some additional, less fundamental, hypotheses are assumed during theory construction. These additional hypotheses cannot generally be obtained from the basic assumptions of the scientific theory. When added to the group of initial assumptions, some of the additional hypotheses may suggest a particular theory, which has a direct relationship only to a comparatively small group of phenomena. All the proponents of nonstandard interpretation share the point of view that no basic theoretical assumptions can be directly compared with experimental and observational evidence. This comparison should be made using the intermediate-level hypotheses. Thus, the Standard Hypothetico-Deductive Model was shown to be unsuitable, since it had imposed over-strict limitations on scientific theory structure. Yet it did have one indisputable advantage - the simple clarity. However, the acceptance of the nonstandard interpretation unavoidably poses the question: if there are no strict rules governing the transition from basic theoretical assumptions to experimental results, how can a fundamental theory be refuted as a whole? If it can not be refuted, how - in real history of science - did one fundamental theory replace another? Were the scientists responsible for the theory change process guided by rational considerations? Were they right or wrong? For example, according to one of the cultivated nonstandard conceptions (Stjopin,1976), mature scientific theory is a set of propositions that describe the relationship between theoretical objects of two types - basic objects and derivative ones. The set of basic objects makes up the aggregate of initial idealizations (the Fundamental Theoretical Scheme or FTS) with no direct reference to experimental data. For instance, the FTS of classical mechanics consist of the Material Point, the Force and the Inertial System of Reference. The derivative theoretical objects are formed from the basic ones according to certain rules. The sets of derivative objects form partial theoretical schemes or PTS. Any mature scientific theory grows due to transitions, in order to describe each new experimental situation, from FTS to PTS. Each PTS construction from the FTS represents a problem that cannot be reduced to a strict algorithm. Hence  it seems, at the first sight, impossible to refute the FTS. On the contrary, if a certain PTS contradicts experimental results, it can always be replaced by another. What then are the reasons for mature theory change? The discovery of a simple divergence between theoretical predictions and experimental results refutes the partial theories but not the fundamental ones. When such anomalies are discovered, PTS can be modified in order to coordinate the whole mature theory with experience (the Duhem-Quine thesis). If one single, arbitrary anomaly can be eliminated, we can just as easily eliminate two, three, four and so on - one after another. Just how many anomalies are necessary to disprove a mature theory? Clearly an infinite number of anomalies must be found - while a mature theory can be adapted to incorporate the results of any finite number of experiments, it can not accomodate an infinite number of them. What is meant by the statement that theory “contradicts an infinite number of experiments”? - The fact is that theory contradicts all experiments of a certain type, i.e. not only that have been performed already, but also those of the future. However, it then follows that one mature theory may contradict another! Only theoretical law can predict the results of future experiments, which have yet to be carried out. As is well-known, a theory is established not only to explain existing experimental data, but also to predict new data. Without claiming to be substantiated, even these straightforward considerations lead to the conclusion that a mature theory can be refuted only by using a critical experiment based on a different and contradictory mature theory. The mere interaction of one “old” theory with experience is obviously insufficient to reproduce theoretically the process of mature theory change. In addition, the interaction of several “old” mature theories should be taken into account. If an experimental anomaly arises as a result of meeting of several mature and contradictory theories, it can not be eliminated by usual PTS modification methods. Its effective elimination demands the resolution of the cross-contradiction. This can be done by establishing a more general theory, containing the old mature theories as its partial ones. The aim of this study is to clarify the above heuristic arguments, to construct an ideal methodological model of mature theory change and to demonstrate the model’s heuristical value in history of science. The model is illustrated with reference to physics in the early 20th century, the three “old” theories in this case being Maxwellian electrodynamics, mechanics and thermodynamics. I hope that the study of a particular period in the history of science is fascinating in itself. It both describes the origin of the special theory of relativity and explains why it was accepted by the scientific community, in some respects superseding existing literary accounts. Further to the belief that the context of justification cannot be understood outside the context of discovery, I maintain that the special theory of relativity was just one stage in the development of quantum theory. Hence  the reasons why it was accepted can not be understood without taking into account Einstein’s works (and the works of his contemporaries) in the quantum domain (see Nugayev,1996, for details). Special relativity and the early quantum theory were created within the same programme of statistical mechanics, thermodynamics and Maxwellian electrodynamics unification. Quantum and relativistic revolutions were simultaneous since they had a common origin - the clash between this three mature theories of the second half of the 19th century that constituted the “body” of classical physics. The very realization of reductionist and synthetic research programmes is brought about by the clash of mature theories which they are designed to eliminate. Within these programmes lie (partially) empirically-equivalent scientific theories (see Nugayev,1985, for details). For example, Lorentz’s electron theory was elaborated within the reductionist programme, while Einstein’s special relativity - within a synthetic programme of mechanics, electrodynamics and thermodynamics unification. In the long run, the programme capable of effectively eliminating the cross-contradiction prevails. Having compared the heuristic potentials of the reductionist and the synthetic programmes, I favour the latter group since it has the following objective advantages. Firstly, synthetic programmes should provide a higher empirically-progressive shift of problems solved than the reductionist ones. Secondly, only these programmes can rationally explain the conservation of the so-called hybrid or crossbred objects which spring from the coincident theories. If we consider the structure of two modern theories - quantum theory and general relativity - we can see that their global theoretical schemes arose from the unification of the crossbred theoretical schemes. This is in no way to demand that each cross-contradiction should be eliminated by choosing a synthetic programme. Or  that all the cross-contradictions that took their places in the history of science were eliminated with the help of synthetic programmes. It means only that synthetic programmes have some objective alluring properties, and that is all that can be said about the competition of synthetic and reductionist programmes in general. This is not to diminish the role of experiments in science. On the contrary ,the model proposed seems to elaborate further the point of view stated in the current literature that both theorists and experimentalists have breaks in their respective traditions, but they are not typically simultaneous(Pickering,1985; Galison,1987). Theory development must have, to some extent, a life of its own. The development of two main cultures within science does not mean that the two do not speak to each other. However, the fact that the model proposed tries to depict breaks in theoretical traditions diminishes its domain of validity in history of science significantly. The split between theory and experiment has become a vital part of the most highly cultivated part of science - of physics - only at the end of the 19-th century. Previously physics were an experimental science. Only after the Second World War were theoretical physicists as numerous as experimentalists (Galison,1987). Hence the theory-change model proposed is not universal. It is not applicable to, say, 18-th century physics, but starts to function only with the establishment of modern physics. I think that the model proposed describes only logico-methodological aspect of immensely complicated process that may be described in general in sociological terms. That is why my aim is to open Pandora’s box only, and not to close it. Yet the aspect investigated proposes the following picture. The history of science can be looked through a fluctuating pattern of research traditions. Of all these traditions, only those can survive that manage to support each other. For instance, the world of “old”, pre-Einsteinian physics was conceptually and socially fragmented. It was split on at least 3 research traditions belonging to electrodynamics, thermodynamics and mechanics. Traditions organized around different groups of phenomena generated little support for one another. The practitioners of each theoretical tradition acknowledged the existence of the other but went their own separate ways. With the advent of relativity and quantum theory, the conceptual unification of worldviews was accompanied by a social unification of practice. Hence the main idea of this paper is rather straightforward. Accounts that had tried to describe mature theory change on the monistic grounds (i.e. considering the development of a single theory, a single scientific research programme, a single paradigm, etc.) failed. Hence one should choose a “pluralistic” background. To understand the real reasons of mature theory change one should consider the interaction, interpenetration of theories, research programmes, paradigms, etc. Every paradigm consists not only of theories, but of values, metaphysical suppositions and research patterns as well. How the interaction of all these components should be described? - I do not know. Yet I insist that the dialectic of the old mature theories is crucial for theory change.

**PART ONE. WHAT MAKES THE ESTABLISHED THEORIES ESTABLISHED?**  Preliminary stage of the occurence of the cross-contradiction consists in the formation of several mature theories with their own domains of validity. By definition, a theory is called the mature theory if all its abstract objects are organized into systems belonging to three levels - the level of basic objects, the level of derivative objects and the level of empirical objects(Stepin,1976). The fundamental laws of the mature theory describe  the relationship between the basic objects . The relationship between the derivative objects is described by the consequences of the fundamental laws. For instance, the electric field at a point E, the magnetic field at a point H, and the current density J are the basic theoretical objects of Maxwellian electrodynamics. Maxwell’s equations describe the relationship between them . The relations between basic objects of Newtonian mechanics are described by Newton’s laws. The derivative objects of Newtonian mechanics are an absolutely rigid body, central field, harmonic oscillator, etc. The relationship between them is described by certain laws of Newtonian mechanics: that is, by the laws of rigid rotation, movement in the central field, etc. The basic objects form the basis of a mature theory. This means that in order for a derivative object to join the system of theoretical objects it must first be constructed from basic objects according to certain rules. Basic theoretical objects are of independent construction; that is, they cannot be constructed from each other. The set of the mature physical theory’s basic objects forms the basis, i.e. a definite subsystem of theoretical objects. All the basic theoretical objects are idealizations and cannot exist as real bodies like tables and chairs. For example, the material point is defined as a body free of dimensions. As for the other basic objects of Newtonian mechanics, it is assumed that an inertial system of reference can be totally isolated from external influence. Though in reality bodies, that can be completely isolated, do not exist at all, even the famous black holes. However, all the basic objects can be compared with certain fragments of Nature. Material points may be compared with bodies whose dimensions can be ignored in the solving of certain problems (see, for instance, Landau & Lifshitz,1973). The force can be compared with the interactions that change the bodies’ states of motion. The derivative subsystems are subordinated to the basic one, but are independent of each other, referring to different fragments of the same domain of validity. Each subsystem is characterized by its own set of notions and mathematical equations that form a special part (section) of the mature theory. For instance, classical mechanics consists of several independent sections: small-oscillations mechanics, mechanics of rigid body rotations, mechanics of movement in a central field, etc. Each of these sections is characterized by its own subsystem of derivative objects. Each subsystem is a model of a particular type of mechanical motion (the small oscillations model, the rigid rotations model, etc.). Relations between the subsystem’s elements are described by particular laws of classical mechanics. In general, the relations between a subsystem of basic objects and a subsystem of derivative ones can be described in the following way. Each derivative system is obtained from the basis by a process of reduction. It means that any mature theory is developed not by formal - logical, mathematical - means only, but also through gedankenexperiments with abstract theoretical objects. The reduction is put into effect by analyzing the character of the empirically fixed domain of validity. This domain can be “seen through” the prism of an ideal model, formed by correlations of basic objects. According to the peculiarities of each concrete experimental situation, various restrictions may be imposed on the system of basic theoretical objects. This enables one to define the system, transforming it into a subsystem of derivative objects. The fundamental equations are then applied to the subsystems of derivative objects. In accordance with the system features, they are transformed into the partial laws. The informal nature of such manipulations converts such an inference into a special problem solving operation. The solutions of such problems are included in a theory at its origin. To a theoretician bothered by applying a theory, they serve as a pattern for subsequent activity. Each problem is solved in accordance with primary paradigms (in Kuhn’s sense). In classical mechanics, the paradigm examples consist of “derivations” from Newton’s laws: the small-oscillations law, the movement in a central field law, the rigid body rotations law, etc. In classical electrodynamics, the paradigm examples are the laws of Biot & Savart, Coulomb, Ampere, Faradey et al., derived from Maxwell’s equations. The construction of derivative objects from basic ones enables one to compare theoretical knowledge with experience, to explain the results of real experiments. To this end, an empirical equation - an intermediate relation - is derived from the partial law. In this equation the special constructs are introduced. In contrast to abstract objects, the newly born constructs are no longer idealizations and can be compared with real bodies now. These constructs are called empirical objects, and their systems - special representations of empirical situations - are called empirical schemes. Empirical objects are not equivalent to real bodies. An empirical object cannot be compared with a single body with which an experimentalist operates, but only with a class of such objects. Consequently, an empirical scheme corresponds not to a concrete experimental situation, but to a type of such situations. For example, the empirical scheme of the Biot & Savare experiment with a magnetic needle and a conductor refers to any experiment with any current in the conductor and any small magnetic needle. Of course, a mature theory becomes established when the links between all the three levels of the organization are installed that makes possible to use the mature theory as an effective instrument for making predictions (see part five for details). All the bonds between all levels of an established mature theory should be rigid ones. This rigidity allows one to connect a prediction referring to the upper level with all levels of a mature theory. Hence it allows one to construct an experimental device to check the prediction. A new result, obtained in the development of mathematical apparatus, immediately influences all levels of a mature theory. Hence a theory can predict, and the predictions can be verified. A mature theory obtains the status of an established one when at least some of its predictions are shown to be successful. It demonstrates that the system of basic objects is complete, and the links between all the three levels are rigid.

**PART TWO. OCCURENCE OF THE CROSS-CONTRADICTION.** Completion of any mature theory T1 inevitably gives rise to questions about the relation of T1’s basis, B1 , to the system of basic objects B2 of another mature theory T2. Are basic theoretical objects from both theories constructively independent? Or is it likely that B1 belongs to a subsystem of derivative objects of T2 (or vice versa)? It is impossible to answer these questions without taking into account the following constructional peculiarities of the derivative objects. (1) The rules for building derivative objects from the basis are not clearly formulated algorithms. They are vaguely determined by the problem-solving examples or paradigms included in theory at its origin. (2) Application of these rules for reducing the basis to a subsystem of derivative objects takes the peculiarities of empirical reality for granted. These peculiarities vary from one field to another. (3) When the physical theories are different, the construction rules differ from each other, being determined by different paradigms. Points (1) to (3) demonstrate how difficult it is to show that T1 is subordinated to T2. Therefore, in everyday scientific practice, the simple conjunction of B1 and B2 is assumed to form a new basis. The true necessity of analyzing the interrelations between B1 and B2 emerges when both theories are needed to explain certain experimental data. It is assumed that experimental data can be described by a system of derivative objects constructed from the basic objects of both theories. Such derivative objects will be called (using Bransky’s notion) crossbred objects or simply crossbreeds. The crossbred objects are constructed from the T1 basic objects. Consequently, the crossbred system will be a subsystem of T1 derivative objects. On the other hand, the crossbred objects also are formed from the T2 basis. Hence the crossbred system will simultaneously be the crossbred system of T2. Consequently, relations between crossbred objects will be described by the partial laws of both T1 and T2. Several “domains of reality” can exist, the description of which may necessitate the joint application of two mature theories. (For the sake of brevity I shall only speak of two theories; in reality, three or more theories are applied, but all these cases can be reduced to 2-theories ones). Hence several crossbred systems may exist simultaneously. The joint application of T1 and T2 for solving a problem will be called, using Podgoretzky & Smorodinsky notion (1980), theories’ cross, while T1 and T2 will be referred as cross theories. The set of statements describing the relations between the crossbreeds will be refered as a crossbred theory. For instance, the completion of Maxwellian electrodynamics gave rise to questions about the relationship between its basis and the system of basic objects of Newtonian mechanics. The task of theoretically describing a black-body radiation spectrum, the electromagnetic radiation process demanded the joint application of both theories (see, for instance, Poincare’s course of lectures “Electricite et Optique”, Paris,1890 and Max Planck’s paper,1906,p.616). Let us consider the examples mentioned above more thoroughly. (a) In order to describe a black-body radiation spectrum theoretically , J.Jeans (1905) investigated the system of standing electromagnetic waves in a closed cavity. By treating such waves as a system of harmonic oscillators (the construction of crossbred theoretical objects), he was able to use a well-known law of statistical mechanics (the equipartition theorem). In this way the dependence of black-body radiation energy on temperature and frequency was discovered. The system of crossbred theoretical objects, the correlations of which form a model of black-body radiation, is a subsystem of classical electrodynamics (i.e. the system of standing electromagnetic waves). On the other hand, this same model forms a subsystem of derivative objects of classical mechanics (a mechanical system with an infinite number of degrees of freedom). (b) Lorentz’s Theory of Electrons, which explained and predicted a large number of phenomena referring to the electrodynamics of moving bodies, provides a classical example of a crossbred theory. Initially, following the traditions of Maxwell and his disciples (Lenard, Hertz), it was assumed that the charges could be considered as a kind of perturbations of the ether. This assumption was based on the key idea of Maxwell’s electromagnetic theory, that displacement current is identical to conduction current. From here he was able to represent the density of electric current in the form of electromagnetic field flow through a cover. But, under the influence of atomistic ideas, Lorentzian electrodynamics were based on the notion of charges’ currents as a system of electrons interacting with the electromagnetic field. The system of electrons is a classical mechanics subsystem. But, as a system of electromagnetic field sources, it is also a subsystem of Maxwellian electrodynamics. © The hypothesis of atomic structure, which assumes the existence of atomic nucleus, was proposed by Nagaoka in 1905 - before Lord Rutherford’s experiments with alpha-particles. When creating planetary model of an atom, the positive charge was defined as an “atomic nucleus”, and electrons were described as being “on a stable orbit round the nucleus”. The system of crossbred theoretical objects, the correlations of which form the planetary model of an atom, is a subsystem of classical mechanics and a component of “motion in the central field” model. On the other hand, this system is a subsystem of classical electrodynamics (Hertz’s oscillator). Relations between the crossbred objects are described by T1 and T2 statements. The crossbred objects belong to the subsystems of both theories. Hence the crossbred construction operation is identical to that of endowing derivative objects, belonging to both theories, with new properties. These additional properties of the first theory’s objects correspond to a new set of relationships transported from another mature theory. Systems of derivative objects of each cross-theory were constructed before they met. Each of them is a summary of corresponding experimental studies carried out independently of investigations connected with another mature theory. Therefore, it is not surprising that, as a result of the formation of crossbred objects, theoretical objects with mutually incompatible properties occur in the same subsystem of derivative objects of one of the crossbred theories. In the above case studies the appearence of objects with mutually incompatible properties was characterized by physicists as “ultraviolet catastrophe” (Paul Ehrenfest’s notion), “the paradox of unstable atom” (Wilhelm Wien’s notion), etc. Let us consider those paradoxes in more detail. (a) As a result of constructing the crossbred system, forming the blackbody radiation model, the free electromagnetic field appeared to possess two additional properties: “to be a system of standing electromagnetic waves” and “to be a mechanical system with infinite degrees of freedom”. Indeed, from the mechanical point of view, the electromagnetic field is a field of electric and magnetic forces that are continuously diffused throughout space. Such a formation has infinite degrees of freedom, in contrast to the finite number of degrees of freedom of a usual body. The material point has 3 degrees of freedom, and its position is determined by 3 coordinates, while the electromagnetic field at a point is determined by all the electromagnetic forces throughout space, i.e. by an indefinite number of magnitudes. Independently of Rayleigh and Jeans, by making use of classical statistics, Einstein demonstrated that at an arbitrary but finite temperature, the density of the electromagnetic field energy should be infinite. This is quite natural, since at an arbitrary finite temperature, the same amount of energy (proportional to temperature) falls on each degree of freedom. However, an infinite electromagnetic field density is incompatible with the second principle of electrodynamics which is based on a statistical-mechanical point of view. One can always extract energy from the cavity containing such radiation and set “perpetuum mobile” of the second kind to motion. Therefore, being a mechanical system with an infinite number of degrees of freedom, the thermal radiation property is incompatible with its property as a “system of standing electromagnetic waves”. (b) As was later emphasized by Albert Einstein, “the weakness of the theory lay in the fact that it tried to determine the phenomena by combining partial and exact differential equations.This method is unnatural.The insufficient part of the theory manifests itself in the admitting finite dimensions of elementary particles and besides, in the necessity of evading the fact that the electromagnetic field on their surfaces should be infinitely great.The theory was unable to explain the tremendous forces that hold charges together on the surfaces of elementary particles” (Einstein,1936). © The planetary model of an atom was constructed as a system of crossbred objects. As a result, the electron was found to have a new property imported from classical mechanics:” to move in a circular orbit round the nucleus”. But, like any accelerated charged particle, the electron must continuously radiate electromagnetic energy. The energy loss should lead to the electron collapsing on the nucleus. Therefore, the electron property “to move in a stable orbit round the nucleus” is incompatible with the property “ to be a negative charge inside the atom”. This paradox, which first appeared in the Nagaoka model, was retained in the Rutherford model. Because of this paradox the scientific community was rather sceptical about the Nagaoka model, but was forced to accept the model of Rutherford because of the experimental evidence. The system of theoretical statements contains expressions regarding the relations between abstract theoretical objects. Therefore, the objects with mutually exclusive properties in the system of derivative objects, should give rise to mutually contradictory statements in the cross-theories. Bearing in mind Podgoretzky and Smorodinsky’s notion(1980), I would like to denote the appearance of incompatible statements when the theories cross by cross-contradiction. There are many examples of such cross-contradictions in the black-body radiation theory, in electrodynamics of moving bodies and in planetary atom theory. (a) “Heat equilibrium of radiation with matter exists” (theorem following from the second law of thermodynamics, see Planck’s lectures on theory of heat) and “heat equilibrium of radiation with matter does not exist” (consequence of Rayleigh-Jeans law, see Lorentz,1909).One participant at the first Solvay conference (1911) remembered later: “This argumentation, analogous to Jeans’s thermal equilibrium analysis, led, however, to the well-known paradoxical result according to which no thermal equilibrium is possible” (Niels Bohr). (b) “What causes all these difficulties? Lorentz’s theory contradicts the purely mechanical notions to which the physicists hoped to reduce all the phenomena of the Universe. Indeed, while there is no absolute motion of bodies in mechanics, and there exists a relative one only, in Lorentz’s theory there is a peculiar state corresponding physically to an absolute rest state: the state when a body is immobile relative to the ether” (Einstein,1910). © “The atom is stable” and “the atom is unstable”.

**PART THREE. THE CROSS-CONTRADICTION ELIMINATION.** The cross-contradiction results from the crossbred-object construction. To eliminate the cross-contradiction, theory T3 must be created, comprising both cross-theories so as to exclude the possibility of constructing crossbreeds from the basises of both theories. Theory T3 will be called a global theory. According to the methodological model I am developing, there are two ways of creating a global theory: reductionist and synthetic.

® Application of a reductionist method of creating a global theory is based on the assumption that the basises of both cross-theories refer to different levels of theoretical object organization. Hence D1, the domain of validity of T1, is a part of D2, the domain of validity of T2. The basis of T2 is called a “true” basis. T2 itself is declared a “fundamental” theory, while T1 is declared a “phenomenological” one. The authenticity of a phenomenological theory must then be established by constructing its basic objects from the basis of a fundamental theory; and by providing that its main laws follow from those of a fundamental theory. Lastly, the basis of a phenomenological theory takes its place as a derivative system of a fundamental theory. The possibility of constructing a phenomenological basis from the basis of a fundamental theory must also be substantiated. The relation between a fundamental theory and a phenomenological one is identical to that between the classical mechanics and one of its parts - the rigid body rotation theory, for instance. The problems of constructing a phenomenological basis from the basis of a fundamental theory are of particular significance for a reductionist programme. They are called fundamental problems (Tisza, 1963). © The synthetic method of creating a global theory is based on the following assumption. The basic objects of both cross-theories are constructively-independent of each other. Their basises belong to the same object-organization level. Hence, cross-contradiction must be eliminated by creating a system of global objects from which the basises of both cross-theories can be constructed. The fundamental laws of both cross-theories should be deduced from those of the global theory. Finally, the basises of T1 and T2 take up their positions as derivative subsystems of the global theory. What are the differences between reductionist and synthetic methods of creating a global theory? First of all, realization of the reductionist programme rules out the use of crossbred objects. They are simply rejected by such a programme. In contrast, the synthetic programme merely rules out using the crossbreeds as derivative objects of the cross-theories. This programme considers the crossbreeds as belonging to the highest theoretical systems’ organisation level. Moreover, application of the synthetic programme results in the creation of a new system of abstract theoretical objects. The rules of reducing the basis to derivative subsystems are determined in the global reductionist theory by puzzle-solving examples contained in the fundamental theory. In contrast, there are no rules for constructing the basic objects of a synthetic global theory. Hence a synthetic global theory can be built by unifying consecutive cross-basises according to a new World Picture (the most vivid example is the creation of Maxwellian electrodynamics). Secondly, synthetic global theory can be formed using mathematical hypothesis method (the creation of general relativity). In the latter case, construction of a theory begins with a search for fundamental equations, and only when they have been found can philosophical interpretation and empirical justification begin. For this reason, 20-th century ways of building a theory differ radically from those of the past. Use of the described ways of eliminating cross-contradiction is based on two equally reasonable, but mutually incompatible assumptions. Therefore, these methods must be used in alternative global theory construction programmes - two reductionist and one synthetic. Since several crossbred systems can be created simultaneously, several synthetic subprograms can exist at the same time.(For instance, Bohr’s and Einstein’s subprogrammes were carried out relatively independently, but subsequently merged into a single one). Each programme creates its own sequence of scientific theories on the basis of one of the above assumptions. Each theory from the sequence is produced by adding an auxiliary hypothesis to the preceding one. Each of the propositions considered above leads to assumptions exclusive to the given programme. Therefore, following the example of Imre Lakatos (1970,p.119), I call these fundamental assertions the hard cores of reductionist and synthetic research programmes. The following statements constitutes the core of the synthetic scientific research programme:” the basic objects of all the cross-theories are constructively-independent”. The opposite is true of the reductionist SRP. In addition, the reductionist “hard core” indicates which theory’s basic objects constitute the true basis. Neither a single crucial experiment, nor a sequence of such experiments can certainly show which programme - reductionist or synthetic - is able to eliminate the cross-contradiction. For example, a reductionist programme is stigmatized as "unable to eliminate the contradiction" only after the demonstration of its incapacity to solve  its fundamental problems . Hence each “hard core” is irrefutable. Each (n+1)-th version of a reductionist or synthetic sequence of theories represents a more adequate realization of a programme than the n-th version. Each of these sequences tends to a certain limit or ideal of the global theory. It is this ideal which “determines” the direction of development of each SRP type.

**PART FOUR. CAN ANY ANOMALY CREATE A PROBLEM SITUATION?**

 Can any anomaly create a problem situation? - Obviously not. Otherwise, science could not proceed further explaining two or three well-known phenomena. What anomalies help to create the problem situations? What anomalies indicate the disagreement of several mature theories with each other? - To answer the question it is necessary to investigate the link connecting the occurence of the anomalies with the appearance of the cross-contradictions. It is necessary to reveal the ways by which the cross-contradiction influences the disagreement of theoretical statements with experimental data. To explain the empirical data, a Partial Theoretical Scheme (i.e. a system of derivative abstract objects) is transformed into an Empirical Scheme. The constructs of Empirical Scheme differ radically from the constructs of the Partial Theoretical Scheme since they are not idealizations now. They can be compared with real objects taking part in real experiments.(In what follows I shall use the ideas of Stepin’s 1976 book, pp.79-97). For instance, consider the situation with a magnetic needle in the vicinity of the conductor carrying a current. To examine the Biot-Savare law validity, one has to compute the needle’s angle of deflection. However, the Biot-Savare formula has nothing to do with real objects. It describes the correlations of theoretical objects only. The theoretical objects involved are : “infinitely small current” and “magnetic field generated by the current”. Hence the Biot-Savare equation cannot be applied directly to explain empirical data. It is necessary to interpret the corresponding quantities as relating to the concrete experimental situation first. That is why a definite consequence of the Biot-Savare law - the empirical formulae - is derived. New quantities are introduced into it. They characterize the needle’s deflection angle and integral conductor configuration. The empirical data should be compared with this formulae only, and not with the Biot-Savare law. Though the elements of empirical schemes can be compared to real objects, they are not identical to them. For example, real magnetic needle and real conductor carrying a current have many properties. In the Empirical Scheme they are represented by the following properties only: “to be guided by the magnetic field” and “to conduct the electric current” and “to have a definite configuration” respectively. Any element of Empirical Scheme can be compared not with a single real object or real experimental device, but with a class of such objects. For instance, the “needle & conductor” empirical scheme refers to any experiment with any conductor and any magnetic needle. An empirical scheme can be obtained not only from theoretical law, but from statistical treatment of empirical data as well. All the objects interacting in real experiments - the object of investigation and the experimental device - are described as having statistically-invariant properties only. It means that they are described as having properties that manifest themselves only under many observations. An Empirical Scheme describes the features typical for many experimental situations. Correspondingly, any subsystem of derivative theoretical objects can be compared with a class of empirical schemes. Hence any system of derivative objects is an invariant content of the empirical schemes. The notion invariant content should not be understood as referring to inductive method of theoretical laws derivation. To obtain a theoretical invariant, one should know beforehand that the set of empirical schemes forms a class. This class is easily revealed only with a help of reduction of derivative subsystems to empirical schemes. Yet comparing the empirical schemes with each other, one cannot easily come to a conclusion that they have common content. The latter is determined by the basis and the rules of derivative objects construction from the basis. The correlations of the derivative objects describe a specific idealized experiment reflecting the most general and salient features of experimental practice. The system of crossbred objects belongs to the derivative subsystems of both cross-theories. Consequently, the occurence of inconsistent statements in the crossbred theory is identical to occurence of inconsistent statements in both cross-theories. The latter is identical to endowing the derivative objects with new properties, incompatible with the old ones. It was already pointed out that any system of derivative objects is an invariant content of a certain class of empirical schemes. That is why the occurence of the cross-contradiction should lead not only to the contradiction between the statements of the crossbred theory and the results of a single experiment, but to the contradiction with the whole class of experiments. For instance, the occurence of the cross-contradiction between mechanics and electrodynamics in the crossbred theory - the planetary atom theory - is identical to endowing to theoretical objects of electrodynamics with new properties incompatible with the old ones. It leads to the following result. The crossbred theory contradicts to the experiments not only with a certain types of atoms - with alkaline metals, for instance, - but to the experiments with all the elements of Mendeleev’s table as well. According to the planetary theory predictions, all the atoms should be unstable. The occurence of the cross-contradiction in the theory of blackbody radiation leads to the contradiction of the crossbred theory not only to the experiments of Lummer & Pringsheim or Rubens & Kurlbaum. The infinity of blackbody radiation energy density led to the situation, when “all the bodies should continuously radiate the electromagnetic waves, and not only outside, but inside also, until all the energy of the bodies is transformed into electromagnetic field energy and the temperature falls down to absolute zero” (Landau,1958,p.81). The cross-contradiction manifests itself not in ordinary deviations of theoretical predictions from experimental results. No theory ever managed to eliminate all its anomalies. When the problem situation is created by the cross-contradiction, the anomalies occur that are out of the domain of usual deviations common for the theory under consideration. Namely these ‘paranormal’ anomalies attract researchers’ attention and the period of” crisis” begins. The paranormal anomalies differ from the usual ones not only in their magnitude. It was not rare in the history of physics when the anomalies were eliminated by non ad hoc modifications of the partial theories. Bit in the cases of paranormal anomalies it is the cross-theories’ inability to eliminate such anomalies that represent a vital factor in the occurence of the problem situation. Why ordinary anomaly cannot be considered as a refutation of a theory? - It is because such an object can be introduced into a derivative theoretical system that is able to change the relations between other theoretical objects. If the anomaly is not an ordinary one but is created by the cross-contradiction, the situation changes gradually. At least two theories deal with the anomaly. In this case any concordance of one cross-theory with the observation data will inevitably lead to deviations of the other cross-theory with the same data (the swing case). As a result, the cross-theories can be brought to agreement with the experimental results only after the cross-contradiction elimination, i.e. only after the creation of the global theory. The model proposed brings some new light on the role of crucial experiments in science. According to the empiricist conception, a single crucial experiment is sufficient to refute any scientific theory . According to the pantheoretical model, critical experiments for mature theories do not exist at all. The empiricist conception is based on the fallacious thesis: there exists the observation language independent of theoretical propositions. The pantheoretic conception exaggerates the theory-laidedness of observations. Hence it is quite natural that, being the supporters of extreme standpoints, the empiricists and the pantheoreticists are right only partly. According to the model developed, there can be any number of critical experiments but only in the problem situation generated by the cross-contradiction. Any anomaly, caused by the existence of the cross-contradiction, is a” crucial experiment”. However, it is crucial not in popperian sense. It cannot refute totally - it can limit the domain of validity only. If the experimental data are out of the crossbred-theory predictions, it means that to eliminate the deviations one has to create the global theory. The usual method of proposing some auxiliary modifications in any of the cross-theories would be useless. It is clear now why certain experiments were considered as ‘crucial’ only with hindsight, only some years after they were performed. It is unnecessary to ask what experiments - of Rubens & Kurlbaum or Lummer & Pringsheim - did actually refute the classical theory of radiation. However, in reality both experiments were crucial, as well as many other ones that have been forgotten up to now. Besides the already mentioned, the list of real crucial experiments includes Young’s experiment, abnormal Mercury perihelion precession observations, etc. The Michelson-Morley experiment is not a crucial one. It is a typical “small crucial experiment” that helped to make a choice between the theories of Fresnel and Stokes debating about partial or complete ether drag. Both theories were proposed within the same Lorentz-Langevin-Wien programme. Let me investigate the example in more details. The classical argument of the empiricists is Lord Kelvin’s prophetic speech, devoted to Two Clouds “that obscure the beauty and clearness of the dynamical theory”. Yet a more thorough analysis reveals that the outstanding protagonist of the Classical Physics spoke not about “facts” and “refutations” but on two paradoxes. Kelvin took  the experimental facts into account only when illustrating the paradoxes.

For instance, the First Paradox (“Cloud”) - “Relative Motion of Ether and Ponderable Bodies” - was dealt with even by Fresnel and Young. It “ involved the question, how could the earth move through an elastic solid, such as essentially is the luminiferous ether?” (Kelvin,1901,p.1).The First Paradox consists in question: if “ether does occupy the same space as ponderable matter” and if “that ether is displaced by ponderable bodies moving through space occupied by ether”, “how then could matter act on ether?” (Kelvin,1901,p.3). The Michelson & Morley experiment is considered only as making one of the paradox’s solution (that of Fresnel) dubious, and the contraction hypothesis of Lorentz & Fitzgerald is called “brilliant” (Kelvin,1901,p.6). The Second Cloud is the Maxwell-Boltzmann doctrine regarding the partition of energy. It was called “the greatest difficulty yet encountered by the molecular theory” even by Maxwell in 1873. It is not surprising that the experiments of Lummer & Pringsheim and Rubens & Kurlbaum are not even mentioned. The occurence of the problem situation (of “crisis” in Kuhnian terms) leads to gradual changes in the activities of scientists involved. They try to exchange the “old” mature theory for new ones. The scientists are inspired by the ideas that will later be reconstructed by the philosophers of science as synthetic and reductionist “hard cores”. As a rule, they cannot realize that the sequences of theories they propose belong to strict and definite Procrustean forms of reductionist or synthetic programmes. Moreover, as a matter of fact they are unaware that they are constructing the global theory.

**PART FIVE. HOW A GLOBAL THEORY IS CONSTRUCTED?**

Is it possible to construct the global theory? Is the probability that scientists can stumble against the global theory in their chaotic wanderings more than zero? Can the scientific community be compared to a flock of monkeys printing on typewriters? Is the probability to find a global theory equal to the probability that the monkeys will print “Hamlet”? Or “Two Dogmas of Empiricism”? In reality a synthetic theory is build by trial and error. Contrary to a reductionist global theory (with definite rules of construction), a synthetic theory is constructed little by little. In the course of the construction, the intermediate hypotheses are proposed that can provide constant empirically-progressive problemshift in comparison with reductionist programmes. Let me demonstrate it. Basic system of theoretical objects, and systems of derivative objects as well, have two indissoluble properties (Stepin,1976). Firstly, any system of theoretical objects, any theoretical model is a representation (see Wartofsky,1979) of some class of objects under consideration. For example, the basis of classical mechanics explains the mechanical motions by an ideal model. The model represents the motions of real bodies by the motions of material points in the inertial systems of reference under the influence of forces. On the other hand, any system of theoretical objects is a model that represents the features of real experimental device. This peculiarity permitted Vyacheslav Stepin to call basic system “The Fundamental Theoretical Scheme” (FTS) and derivative system “The Partial Theoretic Scheme” (PTS). For instance, the FTS of classical mechanics that represents mechanical motion by the motion of a material point in an inertial frame of reference under the influence of the forces describes a gedankenexperiment. The latter describes the main features of the various mechanical experiments with real bodies. The basis of Newtonian mechanics is a generalization of practical operations with real bodies moving along the inclined planes, operations with oscillating pendulums, with billiard balls collisions, etc. In particular, the PTS of small-oscillations constitute a model describing the features of the experiments with oscillations of real pendulums, real stretched strings, etc. Let me imagine now that the reductionist programme had been realized successfully. It means that the global theory was constructed in such a way that the place of the Global Basis was taken by the basis of one of the cross-theories. The basis of the second cross-theory became the system of its derivative objects. This means that one and the same system of theoretical objects describes the features of radically different measuring operations. Their difference is caused by the fact that the basic systems of both cross-theories had been created before they met. They were created as generalizations of independent and different operations. For instance, successful realization of Lorentz-Langevine-Wien reductionist programme (reduction of electrodynamics to mechanics) would mean the following. One of derivative subsystem of maxwellian electrodynamics, consisting of “differentially small current” and “magnetic field of a current” - reflects the essential features of the experiments with the bodies moving along the inclined planes, of the experiments with the rotations of rigid bodies, etc. It is obvious that the paradox described is caused by the fact that the basis of one of cross-theories is unable to generalize the features of radically different measuring operations. The paradox can be eliminated,  and it was - in Lorentz’s theory, for instance, - by introducing the “operationally indefinite” object. It helps to “wash away” the operational foundations of the”fundamental” theory to such an extent that it can accumulate the measuring operations of the “phenomenological” theory . The ideal object “ether” was introduced into the reductionist programme of Lorentz, Langevine and Wien as a “carrier of electromagnetic oscillations”. It is a vivid example of operationally indefinite object. No physical experiment could determine the motion through the ether. This construct was introduced into the system of abstract objects of Lorentz’s theory not due to certain generalizations of measuring operations. It was introduced for the construction of mechanical basis from that of electrodynamics. The material points (the ‘particles’) were to be considered as “ether perturbations”, whereas the forces acting on them were to be determined via the tensions of the ether. The price of such an elimination often appears to be too high. It can lead to a radical decrease of predictive power of a theory. Indeed, what is the cause of this power? If a mature theory is not a direct generalization of empirical data, how can it predict the results of new experiments that are not even performed? How can a mature theory forecast future? According to Stepin (1976), this opportunity is based on the rigid connection between the theoretical basis and real experiments. The link of the basis with experiments is intermediated by the systems of derivative objects. Any basic object represents the characteristic features of the relations of the derivative objects that belong to the lower level of theoretical objects’ organization. Hence to give an operational definition of a basic object is to describe idealized measurement operation, a gedankenexperiment, but not the real one. For instance, the operational definition of electric field density J is given not by the description of real measurements. It is given by the description of relations of Maxwell’s theory abstract objects of “electric field at a point” and “test charge”. These abstract objects are the entities of the partial theoretical schemes of Maxwell’s theory. Their operational status is determined now by real, and not by ideal, measuring operations. For example, the “test charge” is determined through such an action of a massive charged body on the other, when the reciprocal influence of the second body on the first can be neglected. The bond between the PTS level and the level of empirical schemes is installed because all the PTS are the idealized schemes of real interactions observed in real experiments. All the bonds between all levels of a mature theory are rigid ones. This rigidity allows one to connect a prediction referring to the upper level with all levels of a mature theory. Consequently, introduction of operationally-indefinite abstract objects, usual for reductionist theories, should lead to decrease of the predictive power. It does not mean, of course, that a reductionist programme cannot predict at all. (Example: mechanical interpretation of heat). Successful elimination of the cross-contradictions is possible only in a theory that contains all the cross-basises in different systems of derivative objects. Only in synthetic theory can the global theoretical scheme be a model that combines all the salient features of idealized experiments with the abstract objects of both cross-theories. I had previously pointed out that the creation of the global synthetic theory is possible due to constant empirically-progressive problemshift. It is possible to explain now why the synthetic programmes should provide larger empirically-progressive problemshifts in comparison with the reductionist ones. The reason consists in the crossbred -objects utilization by the synthetic programmes and their prohibition in the reductionist ones. In spite of the fact that the crossbred objects should be thrown out of the cross-theories, they are given the rank of global theoretical objects in synthetic programmes. Indeed, according to their definition, the global objects are the objects from which the basises of T1 and T2 are constructed. The global objects contain information about B1 and B2, but the crossbred objects also have this property ! They are constructed from B1 and B2. Moreover, since the construction of the crossbreeds from the basises is possible, the reverse process of reconstructing basises from the crossbreeds also is possible . I have pointed out that in general it is possible to construct several systems of crossbred objects. Each crossbred system contains only part of information about their basises. Only the whole set of various cross-systems possesses all the information about their “parents”. This set is always open for new elements, since it is impossible to declair beforehand that all the cross-domains are known to us. Any mature theory can suffer unrestrained development by the construction of partial theories from the FTS for any new domain of application. That is why the global system must occur only as a result of unification of all the crossystems and cannot live a secluded life. It is always open for new crossbred systems, and the introduction of new elements can endow the old ones with new properties. The scheme described can be illustrated by the example of transition from 19-th century physics to the physics of the 20-th century. The modern quantum theory was created by the unification of Bohr’s crossbred atom models, of Einstein’s crossbred semicorpuscular radiation theory, of special relativity, etc. This process is still not finished. Coordination of Special Relativity with Newton’s theory of gravity led to the General Relativity (GTR) creation. Einstein’s efforts to incorporate Newtonian gravity into the STR framework began in 1907 when he had to prepare a review for “Jahrbuch der Radioaktivitat” (see Vizgin,1981 for details). His first effort was unsuccessful since simple-minded (though lorentz-invariant) generalizations failed to explain the anomalous perihelion motion of Mercury. Yet the creation of GTR led to the problem of the unification of GTR and QFT. This problem is not yet solved, and Stephen Hawking called elucidation of the relation between gravity and quantum theory the most urgent problem facing theoretical physics today. In spite of the fact that the first efforts to reconcile GTR and the quantum theory started from the very moment of GTR creation (theories of Weyl, Cartan, Kaluza & Klein), the substantive progress was attained quite recently, and, at least at the first stages, it seems to have nothing to do with superstrings, supergravity and so on. In accordance with my model I think that the real progress in QFT and GTR unification began with the hybrid objects construction in new crossbred domain called the “Quantum Field Theory in Curved Spaces”.(Birrell & Davies wrote in 1982 the first review under the same title). Hawking’s astonishing 1975 discovery of particle creation by black holes is an obvious example of a cross-theory. The real story started earlier, with Jacob Beckenstein’s pioneer analysis of the black hole entropy. His paper is a masterpiece combining deep physical intuition with outrageous flies of imagination so rare in the dark waters of mathematical speculations. Beckenstein started with a mere analogy between entropy and the surface of blackhole horizon. From the point of view of theory of information, entropy and horizon of a black hole are the quantities of the same type. If a particle gets under the horizon of a black hole, its surface increases due to the mass addition. At the same time entropy increases also, since we cannot look under the horizon to know the state of the particle there. The area of the horizon should be equated to entropy with some proportionality coefficient. J.M. Bardeen, B. Carter and S.W. Hawking(1973) generalized Beckenstein’s intuitive results. They treated the analogy between black hole physics and thermodynamics in more strict and mathematically sophisticated terms. Expressions were derived for the mass of a stationary axisymmetric solution of the Einstein equations containing a black hole surrounded by matter and for the difference in mass between two neighboring solutions. ”Two of the quantities which appear in these expressions, namely the area A of the event horizon and the ‘surface gravity’ k of the black hole, have a close analogy with entropy and temperature respectively. This analogy suggests the formulation of four laws of black hole mechanics which correspond to and in some ways transcend the four laws of thermodynamics” (Bardeen, Carter, Hawking,1973,p.161). Now GTR and thermodynamics were found to be merged into a general theoretical scheme, and the results showed up rather quickly. According to the Second Generalized Law of Thermodynamics, formulated by Beckenstein and Hawking, the flow of entropy across the event horizon of a black hole should increase the area of the horizon A. Entropy + some multiple of A never decreases. If we equate the surface gravity k to temperature, a paradox occurs. If a black hole is immersed in a sea of blackbody radiation at a lower temperature (than that of the black hole), the Second Law will be violated! The only way to avoid the paradox is to admit that a black hole should emit particles at a steady rate with temperature equal to k/2M. Namely that did  Stephen Hawking (1975) by taking quantum-field effects into consideration. At least several lessons can be learned from the story. Firstly, three theories were involved in the occurence of the cross-contradiction: thermodynamics, GTR and QFT. QFT is shown to be a necessary link connecting GTR with thermodynamics. Without QFT, general relativity cannot be reconciled with thermodynamics and statistical mechanics. All the story looks like that: classical thermodynamics “knows” something about the quanta, as if the quantum theory is “contained” in the thermodynamics. In the light of the already told (see Nugayev,1990, for details), this conclusion does not seem strange; the quantum theory is a fusion of thermodynamics, mechanics and electrodynamics. We can conclude that Hawking’s result could be obtained at the end of the 19-th century if we assume that the axioms of thermodynamics are universally valid, which is to say they are assumed to apply to black holes. ”This has perhaps contributed to the idea that gravity has a somehow deeper relationship to thermodynamics than to other branches of physics” (Gould,1987,p.449). From the beginning ,the Quantum Field Theory in Curved Spaces met with a lot of paradoxes caused by the lack of proper agreement between GTR and QFT (Fulling,1973; De Witt,1975). The notion of a particle appeared to be observer-dependent; conformal anomalies occured; various renormalization methods gave different results for vacuum energies; the negative energy fluxes began to fill the space with GTR, and many other delightful things began to bother unhappy theorists and continue to puzzle them now. It is important for the model proposed, that at least one of the leading black-hole theorists had pointed out that the cause of all these paradoxes lies in semiclassical black-hole evaporation theory. ”The gravitational field is treated ‘classically’ (as a spacetime metric) there, while its sources are described in terms of quantum field theory. The basic equations of GTR, Gμν= Tμν, contain incompatible quantities on the two sides of the equals sign. Furthermore, this incompatibility has consequences even at the present experimental scale” (Unruh,1980,p.154). One of the most fascinating crossbreeds here is the QFT vacuum. When it was embedded to GTR derivative system (the blackhole physics), it did acquire a new property - “to produce infinitely great gravitational field”. The methods of its regularization (the cut-off procedures) were elaborated for flat spacetimes only. They are useless in strong gravitational fields. The occurence of the QFT vacuum restructured the relations between the GTR objects, and the process of the global theory construction began. Modern superunification theories (see Chyba,1985), various inflation scenarios are the stages of global theory construction. Vacuum plays the central role here, being the global object of the future theory: “making everything out of nothing” (as Robert Weingard used to say in 1991) during the process of spontaneous symmetry-breaking. The Quantum Vacuum played the leading roles at each stage of the unification of the 4 fundamental forces of nature - in Higgs mechanism establishment (Higgs vacuum), in fifth coordinate compactification in Kaluza-Klein models (the Casimir effect), in Green’s and Schwartz’s superstring model of Quantum Gravity free of gravitational anomalies. ”All the same, it is pretty mind-blowing to reflect that our own four-dimensional world, its geometry, its matter content, and its force may all be just the dynamically determined ground state of vacuum - of a superstring!”(Aitchison,1991,p.193). The creation of the synthetic global theory seems to follow the lines of Einstein and Bohr. However, let me return to the general scheme of global theory creation. Why should the synthetic theories empirically supersede the reductionist ones? The introduction of the crossbreeds creates contradictions in all the cross-theories and forces them to accomodate each other, to “interpenetrate” and to “enrich” each other. For instance, in the case considered, “the general theory of relativity and the quantum theory of fields, taken together in a new synthesis, have thus far enriched each other”(De Witt,1980,p.683). The enrichment manifested itself in the penetration of QFT into GTR (the gravitational field quantization). On the other hand, much less known GTR penetration into QFT manifested in the discovery of the so-called Unruh effect in flat spacetime. ”By building a simple model of a particle detector, and accelerating it in the vacuum state in flat space-time, it is possible to show that such a detector behaves exactly as if it were immersed in a thermal sea of particles of temperature T = 8πa/kc “(Unruh,1980,p.154). The meeting of T1 and T2 increases their domains of validity on D2 and D1 respectively. The domain of validity of T1 expands owing to D2, and vice versa. The domain of validity of both cross-theories becomes equal to 2(D1+D2). For example, the creation of the photon theory (and of special relativity) was due to interpenetration of statistical mechanics and thermodynamics (Willard Gibbs’s and Albert Einstein’s investigations in the domain of statistical thermodynamics), of statistical mechanics and electrodynamics (Einstein’s 1904 papers on fluctuations of electromagnetic field), of thermodynamics and electrodynamics (Max Planck’s pioneered introducing the notions of temperature of radiation and entropy of radiation), and of Newtonian mechanics and Maxwellian electrodynamics (principle of relativity, corpuscular theory of light). The development of Einstein’s ideas by Louis De Broglie (see Pais,1980, for details) consisted in endowing the “ponderous matter” with wave properties, etc. Thus , the crossbred objects are the “channels” through which the ideas and methods of the cross-theories interpenetrate. Let us compare synthetic theories with reductionist ones, that forbid the existence of the crossbreeds. Consider the case that is most favourable for reduction - when the fundamental problems are successfully solved, and the domain of validity of the global theory became larger because D2 was added to D1.The “fundamental” theory T1 have penetrated into the “phenomenological” theory T2, but the reverse process is forbidden. That is why the domain of validity of the synthetic ideal is two times larger than the domain of validity of the reductionist ideal. Namely that peculiarity should provide the victory of synthetic programmes over their reductionist rivals. In spite of the fact that each global theory should eliminate the cross-contradictions according to the model proposed, the real history of physics is more complicated. The process of global theory construction may last for centuries embracing new cross-domains with the cross-contradictions play the role of “driving forces” in the creation of new theories. In the case of a clash between GTR and QFT, the methodological scheme can be illustrated by the following quotation. ”It is ironic that just at the time when the experimental tests are becoming possible, are being performed, and are verifying the predictions of the theory, the most determined assault on the structure of the theory itself is taking place. In the attempt to make general relativity compatible with quantum theory of fields, many feel that the theory must be altered in some fashion. The most notable example of this is, of course, supergravity, with its addition of the gravitino” (Unruh,1980,p.153). The most remarkable feature of the modern supergravity theories consists in that these theories were constructed without experimental results.” The second reply to such criticisms is that we have already a powerful ‘experimental’ fact that needs to be explained, and that is the logical inconsistency of the two theories”(Unruh,1980,p.154). When constructing the global theory, the experimental data are taken into account indirectly, being embedded into pieces of theory. The role of contradictions between Theory and Experiment is played by the cross-contradictions between several theories. But the fact is that the construction of the Global Theory had already begun. Indecisive results including supergravity were obtained without any experimental results. This is not to establish the complacent standpoint, since too many steps are to be made until we declare that the unification machine is at hand. What is crucial in establishing the supergravity is its empirical justification. The latter should consist in establishing the operational status of the concepts involved. This status can be obtained by ideal measurement procedures first of all that are analogous to Bohr-Rosenfeld procedures in quantum electrodynamics. To give an operational definition of a physical quantity, connected with a basic object, is to give a description of idealized measurement procedures. ”It was only by asking questions about measurements, about how the various phenomena would affect measuring instruments such as real-model gravity wave detectors or observers falling through the ‘singularity’ at R=2M of the Schwarzchild metric, that these issues were resolved”(Unruh,1986,p.128). It is no wonder that the most intriguing results were obtained in this direction of research. I am talking about the famous Unruh effect: “the lesson of general relativity was that the proper questions to ask of a theory are those that concern the behaviour of detectors that have been fashioned to detect the effects that concern one. For example, in trying to decide whether or not particles are created, one needs to define a particle detector within the theory; i.e. some model of a physical system that will respond to the presence of a particle. In my attempt to apply this philosophy in the mid 1970’s, I looked at the behaviour of a simple model of a particle detector (1) for some quantum field, which, for simplicity, I took as a massless scalar field F” (Unruh,1986,p.128). The operational analysis of the concepts involved is necessary for making correct predictions.

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