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Preface

For what is time? Who can readily and briefly explain this?
Who can even in thought comprehend it, so to utter a word about it? . . .
My soul is on fire to know this most intricate enigma . . .
I desire to know the force and nature of time, by which we measure the motions of bodies . . . for times are made by the alternation of things . . . because, without the variety of motions, there are no times . . .
St. Augustine, The Confessions

The aim of this book is to discuss thoroughly the problem of time in the multidisciplinary approach. The meaning of time is the remaining mystery. In this book, we draw attention to the connection of temporal evolution and directionality of time, which is one of the big open questions in physics. In our approach we discuss and analyze foundational issues of the problem of time and asymmetry of time from a unified standpoint.

The objective of this study is to provide a thorough discussion on the evolution of time and its implications with regard to the approach to equilibrium of open systems in the context of non-equilibrium statistical thermodynamics. We attempted to show the development of the concept of time as the common notion for various disciplines: philosophy, history and natural sciences.

It is known that the irreversibility in time of all processes occurring in nature plays an important role from various points of view. The theories of non-equilibrium phenomena and irreversible processes are aimed to formulate an adequate formalism for their description. By definition, evolution is the alteration of the state of the system with the passage of time. In general, this alteration is a random process.

Thermodynamic properties of many-particle systems may be derived through appropriate thermodynamic functions and macroscopic (thermodynamic) entropy. Entropy is a non-conservative quantity and as such is a basic concept of thermodynamics and a distinctive, marked characteristic of thermal phenomena in the real world. According to the laws of thermodynamics, reversible evolution is an evolution with constant entropy. In the thermodynamic approach, entropy generation is a measure of irreversibility. In other words, entropy changes characterize the irreversible behavior in a system during a process.

In this context it is of great importance to emphasize the problem of averaging of the observable variables of complex many-particle systems. As it was formulated by Gell-Mann in his book, *The Quark and the Jaguar*: "entropy is useless without coarse graining ... entropy, like effective complexity, ... depends on coarse graining — the level of detail at which the system is being described". The present book is aimed to develop and clarify this statement from various sides. In order to understand how the complex concept of entropy emerged in the various natural processes, we will discuss the numerous problems of physics, cosmology and biology.

It is worth mentioning that a close relationship exists between the concepts of entropy and probability, the most famous of which is associated with the name of Boltzmann. Hence, entropy and probability are intrinsically related. It can be showed that the concavity property of entropy is related directly to a given probability distribution function for an ideal gas in which binary collisions dominate. Concavity is directly related also to the logarithm of a probability distribution. It is interesting that by relating entropy directly to a probability distribution function one can show that a non-equilibrium version of the entropy function may be deduced.

In the context of temporal evolution, it is of importance to emphasize that in the structure of thermodynamics one of its basic law, namely the second law, differs very much from other general laws of physics. It is not an equation, but instead states an inequality, which becomes an equality only in the limiting case of a reversible process. There are difficulties with the realization of this limit, because a reversible process is one in which the thermodynamic system never deviates appreciably from equilibrium. However, finite time process involves a disturbance of equilibrium. As a result, it is difficult (if not impossible) to derive the fully correct equations concerning temporal evolution. It has even been said sometimes that time appears in thermodynamics not as a quantity but only as the indicator of the sense of a quantity, the change of entropy.

The second law of thermodynamics states that for a closed system entropy does not change. In general, the total entropy of a system cannot decrease without increasing the entropy of some other systems. On the other hand, *time* is not the usual physical time variable, but it is a special *device* used for the temporal ordering of states. However, the increase in entropy is not the unique source of temporality. Many questions concerning the nature of time and its directionality are still under intensive debates and require additional thorough consideration.

The aim of the present interdisciplinary consideration was to carry out a comparative analysis of the notions of thermodynamic entropy, information entropy and entropy of non-equilibrium states as well as flow of entropy from a critical perspective. The problems of temporal evolution and time directionality have been discussed in this context as well. The interrelation of these notions has been studied, focusing on non-equilibrium entropy. The book was aimed to clarify the notion of entropy, entropy production and its generalizations. The Boltzmann, Gibbs, von Neumann, Shannon, Renyi, Tsallis and others types of entropy have been considered concisely. The notions of the steady state, local state and local equilibrium have been analyzed thoroughly to expose similarities and dissimilarities of various approaches to the definition of the entropy of non-equilibrium states. The extremal principles for entropy and entropy production have been analyzed and discussed in this connection. The purpose of the present study was to elucidate certain aspects of the non-equilibrium statistical mechanics, namely the principal role of the correct description of the temporal evolution of a system and the corresponding procedure of averaging. We also touched tersely the intriguing problems of directionality of time and causality as well as relevance of constructal law that accounts for the phenomenon of evolution.

Heat, entropy and temperature are the key fundamental concepts of thermodynamics. The book gives a concise overview of the fundamentals and applications of these basic notions of physics, including the new developments on this issue. These include the finite-size systems, negative absolute temperatures, the Carnot efficiency, the second law of thermodynamics. We propose to look at these issues under a new angle, namely by considering their as certain exotic thermodynamic states. For the ordinary thermodynamic states, temperature increases with increasing energy. It changes from zero, asymptotically approaching positive values (up to infinity) when the energy increases. For exotic thermodynamic states, entropy may not increase when the energy increases, i.e. when energy is added to the system.

We discussed and critically examined various opinions and both the applications and foundations of the negative absolute temperature concept. We were focused on the analysis of physical clarity of the various approaches to the problem as well as on their consistency with the basic notions of statistical thermodynamics such as the thermodynamic limit.

Our aim was to discuss tersely current theories and underlying notions, including the interdisciplinary aspects, such as the role of time and temporality in quantum and statistical physics, biology and cosmology. We compare some sophisticated ideas and approaches for treatment of the problem of time and asymmetry of time by considering thoroughly the second law of thermodynamics, non-equilibrium entropy, entropy production and irreversibility in various aspects. The concept of irreversibility has been discussed carefully and reanalyzed in this connection to clarify the concept of entropy production, which is a marked characteristic of irreversibility. The role of boundary conditions in the distinction between past and future has been discussed with attention to this context. The book as a whole includes also a synthesis of past and present researches and a survey of methodology. We analyzed also some open questions in the field from a critical perspective.

Generic methods and theories have been described concisely, followed by applications and examples in physics and biology. The book aims to help the broad audience of potential readers (graduate and postgraduate students, physicists, chemists, biologists, philosophers and historians of science) build, systematically and coherently through basic principles, their own understanding of basic concepts and theoretical methods, which they may be able to apply to a broader class of physical, chemical and biological problems.

In our interdisciplinary treatment, we aimed to show that the notions of thermodynamics and statistical physics may be applied effectively to a broad class of complex biological problems. As it has been mentioned, the irreversibility in time of all processes occurring in nature plays an important role. It is of great importance for living matter. We aimed to provide a thorough qualitative discussion on the time evolution in biological systems and its implications with regard to irreversible processes in living organisms, including the aging. The role of the thermodynamic functions: energy, entropy, free energy and time patterns, and information have been discussed in this context. The specific role of time, which is the marked characteristic of natural phenomena in the real world, in understanding of the principles of evolution has been illustrated by applications and examples in biology. We were focused on the basic ideas and theories in the realm of biophysical studies to emphasize and address the operational ability of the thermodynamical and statistical–mechanical methods and their broad applicability to distinct problems in this area. We have discussed some of these results and achievements briefly. The relevance of the methods of thermodynamics, statistical physics, theory of information for biology and biophysics has been elucidated.

Before considering special questions, a very brief summary of the interrelation of thermodynamics and statistical mechanics will be of instruction. The book contains a few introductory pedagogical sections with a hope to make the presentation more coherent and self-contained. Many chapters include also varied additional information and discuss many complex research areas which are not often discussed in other places. We have aim to make the separate chapters self-contained, so some minor repetitions were admitted for reader convenience.

Our main intention was to present here the physical results rather than a mathematical formalism. Hence, we have stayed away from technicalities and have concentrated on the essence of the problems from the physical viewpoint. A common thread across this book is the search for better understanding and clarification of the notion of time in the natural sciences from various points of view.

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Chapter 1

The Enigma of Time

1.1 Time. General Aspects

Time is an abstruse concept. Time was a strange and recalcitrant phenomena through the ages. The problem of time was and still is an extraordinary challenge, the complete rationale for which have not being done yet and is in a thick fog. In addition, the notion of time has diverse understanding and interpretations in various cultures [1–4]. The speculations about time are lost in a fog of mythology, popular legends, and folklore. According to Jung [5], "myths are the earliest form of science".

There is an intimate connection of time and the rhythm (cyclic motion, pendulum, metronome), including the rhythm of the nature [6], i.e. the calendar [7]. The capacity to measure time is among the most important of human achievements and the issue of when time was created by humankind is critical in understanding how society has developed [8–11]. Intuitively time was considered as a kind of external device for fixation of the changes (time as a measure of a motion). From the point of view of an astronomer [9] "time being an immaterial quantity, it has to be referred to a material phenomenon in order to be measured".

Wilcox in his notable work [12] attempted to discover an approach to narrative and history consistent with the discontinuous, relative time of the twentieth century. He showed how our B.C./A.D. system, intimately connected to Newtonian concepts of continuous, objective, and absolute time, has affected our conception and experience of the past. He demonstrated absolute time's centrality to modern historical methodologies and the problems it has created in the selection and interpretation of facts. Inspired by contemporary fiction and Einsteinian concepts of relativity, he concluded his analysis with a comparison of our system with earlier, pre-Newtonian time schemes to create a radical new critique of historical objectivity.

The phenomenon of time can be characterized as variable quantity which is hardly to define precisely beyond the concrete context [13–16]. The very this circumstantial evidence pointed out that the time is a fundamental concept.

Many inner difficulties and caveats were generated about the notion of time because of a lack of clear and consistent case study of that problem. The numerous ideas and approaches should be challenged as strongly as possible to test their soundness [3, 17, 20–23].

The logical idea which is is relevant to the case, is that time is a concept based on experience of change and sequence. It includes inwardly the notions of past, present, and future. To implement this idea, the numerous attempts have been carried out to give a unified definition of time. To define concisely what the time is the hundreds of compound sentences or persuasive definitions were generated, for example: time may be considered as the indefinite continued progress of existence and events in the past, present, and future regarded as a whole. Other complementary definition: time is a continuum of non-spatial character in which events occur in apparently irreversible succession from the past through the present to the future.

Time flies or passes. The continuance of events in time is the duration, so time is the unlimited duration. The present is the time *now*. The past is the time earlier than now. The future is the time after the present, time yet to come. Hence the passage of the time has the direction [24]: from past to future.

The concept of time [25, 26] and the phenomenon of time itself have been discussed and debated from various points of view since ancient epoch [23, 27–30]. The conception that the Universe is a rational system, working by discoverable laws, seems to have first appeared as a definite belief among the Ionian Greeks in the sixth century B.C. [31, 32].

Ancient philosophy had a concern in time, but the real philosophy of time may be counted from the works by Aristotle [33–35]. Aristotle's definition of time as "*a number of motion with respect to the before and after*" met a favorable reception by commentators and followers. Roark presented in his book [34] an interpretation of the definition that renders it not only non-circular, but also worthy of serious philosophical scrutiny. He showed how Aristotle developed an account of the nature of time that was inspired by Plato while also thoroughly bound up with Aristotle's sophisticated analyses of motion and perception. When Aristotle's view is reasonably properly understood, Roark argues, it is immune to devastating objections against the possibility of temporal passage articulated, for example, by McTaggart [36] and other twentieth-century philosophers.

"The Unreality of Time" is the best-known philosophical work of the Cambridge idealist McTaggart (1866-1925), who offered a phenomenological analysis of the appearance of time. In his work, first published as a journal article in *Mind* in 1908, McTaggart claimed that time is *unreal* because our descriptions of time are either contradictory, circular, or insufficient. McTaggart insisted that, since every event has the characteristic of being both present and not present (i.e., future or past), the time is a self-contradictory idea. But the Roark's fresh approach [34] and his clever interpretation of Aristotle's temporal theory shed new light on that and similar arguments and showed its weakness.

The paper by by McTaggart [36] influenced a number of twentieth-century philosophers. As a result, the two distinct approaches to the theory of time were formed: the tensed and the tenseless [37]. What is of importance, it is the fact that many philosopher under the influence of the relativistic theory of the space-time accepted the tenseless theory [38–41].

There are various aspects of time to be discussed [40] to illuminate some of humanity's most fundamental and enduring questions. What role, if any, does language [43, 44] play in giving us an insight into temporal reality? General aspects of the philosophy of time covers subjects such as time and change, the experience of time, physical and metaphysical approaches to the nature of time, the direction of time, time travel, time and freedom of the will, and scientific and philosophical approaches to eternity and the beginning of time.

For example, the book [41] presents the latest cutting-edge research in the philosophy and cognitive science of temporal illusions. The book discusses four broad and interdisciplinary topics: illusions of temporal passage, illusions and duration, illusions of temporal order and simultaneity, and the relationship between temporal illusions and the cognitive representation of time.

Illusion and error have long been important points of entry for both philosophical and psychological approaches to understanding the mind. Temporal illusions, specifically, concern a fundamental feature of lived experience, temporality, and its relation to a fundamental feature of the world, time, thus providing useful insight into investigations of the mind and its relationship with the world. The existence of temporal illusions crucially challenges the naive assumption that we can simply infer the temporal nature of the world from experience.

In this context it is worth mentioning the paper "The Illusory Flow and Passage of Time within Consciousness: A Multidisciplinary Analysis" [42]. In that paper flow and passage of time puzzles were analyzed by first clarifying their roles in the current multidisciplinary understanding of time in consciousness. All terms (flow, passage, happening, becoming) were carefully defined. Flow and passage were defined differently, the former involving the psychological aspects of time and the latter involving the evolving universe and associated new cerebral events. The concept of the flow of time (FOT) was deconstructed into two levels: (a) a lower level - a perceptual dynamic flux, or happening, or flow of events (not time); and (b) an upper level - a cognitive view of past/present/future in which the observer seems to move from one to the other. With increasing evidence that all perception is a discrete continuity provided by illusory perceptual completion, the lower-level FOT is essentially the result of perceptual completion. The brain conflates the expression flow (passage, for some) of time with experiences of perceptual completion. However, this is an illusory percept. Converging evidence on the upper-level FOT reveals it as a false cognition that has the illusory percept of object persistence as its prerequisite. To research this argument, an experiment that temporarily removes the experience of the lower-level FOT might be conducted. The claustrum of the brain (arguably the center of consciousness) should be intermittently stimulated to create a scenario of discrete observations (involving all the senses) with long interstimulus intervals of non-consciousness and thereby no perceptual completion. Without perceptual completion, there should be no subjective experience of the lower-level flow of time.

The polemics and debate on the nature of time show that time is an extraordinary interdisciplinary and multifaceted notion [39, 45–47]; moreover it is a burning and controversial issue [48–52]. The new discoveries in physics during the 20th century have stimulated intense debate about their relevance to previous theological questions [53, 54]. Views range from those holding that modern physics provides a surer road to God than traditional religions, to those who say that physics and theology are incommensurable and so do not relate. The results of modern physics has stimulated renewed theological discussions on the connections between physics and the theological implications [55]. However, it is of great importance to distinguish the actual results of modern physics from speculations. Indeed, some authors even speculated that time is "an independent entity which cannot be reduced to the concept of matter, space or field" [56].

Haught in his book "Is Nature Enough? Meaning and Truth in the Age

of Science" [57] examined the dialogue of science with religion. The belief that nature is all there is and that no overall purpose exists in the universe is known broadly as "naturalism." Naturalism, in this context, denies the existence of any realities distinct from the natural world and human culture. Since the rise of science in the modern world has had so much influence on naturalism's intellectual acceptance, the author focuses on "scientific" naturalism and the way in which its defenders are now attempting to put a distance between contemporary thought and humanity's religious traditions. Haught seeks to provide a reasonable, scientifically informed alternative to naturalism.
The literature on the diverse aspects of time and temporality contains many thousands of items and its number grows quickly [58]. For example, in the bibliographic collection [58] the literature on the problem of time has been classified according to the following subdivisions:

- 1 General Works
- 2 Anthropology and Culture
- 3 Biology
- 4 Calendars and Clocks
- 5 Economics
- 6 Futures Studies
- 7 Geography
- 8 Geology
- 9 Music
- 10 Philosophy and Physics
- 11 Physiology
- 12 Political Science
- 13 Psychiatry and Psychoanalysis
- 14 Psychology
- 15 Sociology
- 16 Speech and Communication
- 17 History
- 18 Linguistics
- 19 Literature
- 20 Management and Organizational Studies
- 21 Miscellaneous

This list confirms that time is an interdisciplinary and multifaceted notion, which supposes the broad variety of approaches [59, 60]. The volume *Perspectives on Time* [59] deals with the problem of time from different perspectives such as logic, physics and philosophy. The informative issues which are addressed in this book concern the direction of time, the reality of tenses, the objectivity of becoming, the existence in time, and the logical structures of reasoning about time. The papers have been written based on different approaches, partly depending on whether the authors subscribe to an A-theory or a B-theory of time. However, in regard to the *theory of time* in general sense, as an attempt to explain a certain class of phenomena by deducing them as necessary consequences of other phenomena, regarded as more initial, no successful formulation exist [61].

1.2 Time, Causality and Human Context

Causation is a multifaceted notion [62]. Indeed, "the search for causes is so central to science that it has sometimes been taken as the defining attribute of the scientific enterprise. Yet even after twenty-five centuries of philosophical analysis the meaning of "*cause*" is still a matter of controversy, among scientists as well as philosophers. Part of the problem is that the servicable concepts of causation built out of Necessity, Sufficiency, Locality, and Temporal Precedence were constructed for a deterministic world-view which has been obsolete since the advent of quantum theory. A physically credible theory of causation must be, at basis, statistical. And statistical analyses of causation may be of interest even when an underlying deterministic theory is assumed, as in classical statistical mechanics. It is easier to say what statistical causation is not, than to say what it is. Causation is not mere correlation".

There is a tacit agreement with the proposition that everything in the universe has a cause and is thus an effect of that cause. This means that if a given event occurs, then this is the result of a previous, related event. If an object is in a certain state, then it is in that state as a result of another object interacting with it previously. This is the principle of causality formulated by Plato: *everything that becomes or changes must do so owing to some cause; for nothing can come to be without a cause.* Historically, Newton set down new principles by recognizing that any law relating cause and effect was likely to be approximate and that the experimental evidence that could be observed was probably a special case of a more general situation, and by adopting a methodology of focusing on the exceptions to successively improve the theoretical foundations of empirical knowledge.

One of the basic theme of various studies on time is the interconnection of

time and causality [63, 64, 67, 70]. Indeed, the nexus of cause and effect is of special importance in the human's life and in all the natural sciences. The causality is an unavoidable factor which brings together researches on all facets of how time and causality relate across the various sciences. Time is fundamental to how human being perceive and reason about causes [70]. That a cause happens before its effect has been a core, and often unquestioned, part of how we describe causality. Researches across disciplines shows that the relationship is much more complex than that. In addition, authors [70] reconsidered carefully what that means for both the metaphysics and epistemology of causes - what they are and how we can find them. Across psychology, biology, and the social sciences, common themes emerge, suggesting that time plays a critical role in our understanding.
Maudlin in his interested study [64] advocated an original approach to causation, in opposition to counterfactual analyses. Maudlin proposed to build on a foundation in which laws of nature and a directed time are assumed as primitives which generate the cosmic pattern of events. He distinguishes some laws of temporal evolution as fundamental from other special laws. In this approach one selects a relevant time for characterization of the state of the world and its alteration. Maudlin speculates that time passes, i.e., together with primitive (irreducible) physical laws, time's passage is a key element of the cosmic structure. In his view, the passage of time is neither a simple psychological phenomenon nor a kind of whole truth. In other words, time passes because that is what ordinary experience suggests the physical world is like; we do not have at the moment absolute physical arguments to think otherwise. Maudlin tells us that the passage of time is an intrinsic asymmetry in the temporal structure of the world with no spatial counterpart. In terms of a classical space-time theory it is possible to represent such an asymmetry by assuming a primitive temporal orientation, i.e., a partition of the time-like vectors at each space-time point into two separate sets in a way that varies smoothly from point to point (at least locally), together with a designation of one set as future-directed, the other as past-directed.
Norton [65] analyzed attempt to reconstitute a local principle of causality in physics. Some researchers have argued that the requirement that electromagnetic dispersion processes are causal; this added an empirical content which is not relevant for electrodynamic theory. Norton [65] urged that this attempt to reconstitute a local principle of causality in physics fails. An independent principle is not needed to recover the results of dispersion theory. The use of *'causality conditions'* proves to be the mere adding of

causal labels to an already presumed fact. If instead one seeks a broader, independently formulated grounding for the conditions, that grounding either fails or dissolves into vagueness and ambiguity, as has traditionally been the fate of candidate principles of causality.
In his reply, Frisch [66] insisted that classical dispersion relations are derived from a time-asymmetric constraint. He argued that the standard causal interpretation of this constraint plays a scientifically legitimate role in dispersion theory, and hence provides a counterexample to the causal skepticism advanced by Nortonand others. Norton [65] argued that the causal interpretation of the time-asymmetric constraint is an empty honorific and that the constraint can be motivated by purely non-causal considerations. Frisch [66] responded to Norton's criticisms and argued that Norton's skepticism derives its force partly by holding causal principles to a standard too high to be met by other scientifically legitimate constraints.
Heylighen discussed the self-organization of time and causality [67]. The inherent difficulty is that all scientific theories of origins and evolution consider the existence of time and causality as given. Heylighen tackled this problem by starting from the concept of self-organization, which is seen as the spontaneous emergence of order out of primordial chaos. Self-organization can be explained by the selective retention of invariant or consistent variations, implying a breaking of the initial symmetry exhibited by randomness. In the case of time, we may start from a random graph connecting primitive "events". Selection on the basis of consistency eliminates cyclic parts of the graph, so that transitive closure can transform it into a partial order relation of precedence. Causality is assumed to be carried by causal "agents" which undergo a more traditional variation and selection, giving rise to causal laws that are partly contingent, partly necessary.
Frisch reconsidered the causal reasoning in physics in his book [68]. Much has been written on the role of causal notions and causal reasoning in the so-called '*special sciences*' and in common sense. But does causal reasoning also play a role in physics? Frisch argued that, contrary to what influential philosophical arguments purport to show, the answer is yes. Time-asymmetric causal structures are as integral a part of the representational toolkit of physics as a theory's dynamical equations. Frisch developed his argument partly through a critique of anti-causal arguments and partly through a detailed examination of actual examples of causal notions in physics, including causal principles invoked in linear response theory and in representations of radiation phenomena. This analysis offers a new perspective on the nature of scientific theories and causal reasoning in natural

processes.
Farr analyzed [69] the question: What would it be for a process to happen backwards in time? Would such a process involve different causal relations? It is common to understand the time reversal invariance of a physical theory in causal terms, such that whatever can happen forwards in time (according to the theory) can also happen backwards in time. This has led many to hold that time reversal symmetry is incompatible with the asymmetry of cause and effect. Farr [69] critiqued the causal reading of time reversal. First, he argued that the causal reading requires time-reversal-related models to be understood as representing distinct possible worlds, and on such a reading causal relations are compatible with time reversal symmetry. Second, Farr argued that the former approach does however raise serious sceptical problems regarding the causal relations of paradigm causal processes, and as a consequence there are overwhelming reasons to prefer a non-causal reading of time reversal whereby time reversal leaves causal relations invariant. Author concluded that on the non-causal reading, time reversal symmetry poses no significant conceptual nor epistemological problems for causation.
Riek examined the interconnection of the entropy and causality [71]. His theses are connected with the fact that the second law of thermodynamics, with its positive change of entropy for a system not in equilibrium, defines an arrow of time. Causality, which is the connection between a cause and an effect, requests a direction of time by definition. It was noted that no other standard physical theories show this property. Riek attempted to connect causality with entropy, which is possible by defining time as the *metric of causality*. Under this consideration that time appears only through a cause-effect relationship ("measured", typically, in an apparatus called clock), it was demonstrated that time must be discrete in nature and cannot be continuous as assumed in all standard theories of physics including general and special relativity, and classical physics. The following lines of reasoning were included: (i) (mechanical) causality requests that the cause must precede its effect (i.e., antecedence) requesting a discrete time interval > 0. (ii) An infinitely small time step $dt > 0$ is thereby not sufficient to distinguish between cause and effect as a mathematical relationship between the two (i.e., Poisson bracket) will commute at a time interval dt, while not evidently within discrete time steps Δt. As a consequence of a discrete time, entropy emerges connecting causality and entropy to each other.
The causality in the human context was discussed ingeniously by Ellis in his book *How Can Physics Underline the Mind?* [72]. "As the title sug-

gests, the subject of that book was the emergence of complexity and the mind, focusing on the role of top-down causation. The aim was to engage with the complexity of the emergence of life and the mind out of the underlying physics. What makes this possible? The world of biology, where purpose and adaptation abound, is quite different from the natural world of rocks, oceans, atmospheres, planets, stars, and galaxies, where impersonal forces hold sway. Yet both are based on the same underlying physics. How can such different outcomes emerge from the same underlying particles and forces? Can we identify the key enabling principles?" Ellis continues [72]: "A stark lacuna lies at the heart of science: half the causal narrative has been omitted!" Ellis makes a cogent and compelling case that the causal architecture of the universe is subtler and richer than the austere reductionist picture dictates. In his book, the author assembled evidences and arguments from across the great sweep of intellectual inquiry, from pure mathematics and computation to neuroscience and engineering, and weaves them into a formal, systematic framework for understanding physical reality as we observe it, and for taking seriously human agency and moral choice. This book set the agenda for the next leap forward in humanity's attempt to make sense of how the world actually works.

To summarize, the philosophy of time discusses our experience of time from a broadly naturalistic perspective. It is rich in detail and argument [48–50, 73]. However, as critics may tell sometimes: Philosophers may conduct interesting debate on that issue and on various details, but they can not guarantee fully to state and prove the inherent essentials about the real nature of time.

During the last decades the focus of the studies on time shifted to physics [74], astrophysics [75, 76] and cosmology [77, 78]. Indeed, there is also the physical time, or more precisely, the space-time [73, 79–83], which is a four-dimensional manifold (or a (3+1)-dimensional structure). However our personal experience of time suggests to us a picture of the flowing time, which is manifested in the laws of classical physics, where time takes the role of a global real-valued parameter. Modern physics modified substantially this intuitive picture. Theory of relativity proved that time is observer-dependent and is not absolute. The quantum mechanics states that the time of events cannot be determined arbitrarily precisely. As a result, there is a remarkable discrepancy between the observables in quantum mechanics: whereas position measurements are described in terms of Hermitian operators, there is no such operator for time measurements. This is the so called *problem of time in physics* [83]. Does it means that there are two distinct pictures or images of time and any project of reconciliation is impossible?

There are numerous attempts and approaches to the reconciliation of the sciences and the humanities [3, 17, 23, 48, 49, 84–87]. However the conflict is still persists and reconciliation is the desirable aim only. There are many differences between these two systems [88–90]. According to Jones [85]: "We want to understand, as well as to control, the world around us". Jones [85] continues: "It is possibly to distinguish one scientific language from another in terms of the different types of scientific objects they employ . . . The various physical sciences can be arranged in a rough order, or series of levels; though each language has its own scientific object, the scientific objects of a language at a lower (i.e. less general) level are usually translatable into scientific object at a high (i.e. more general) level".

It seems that the notion of *time* is hardly may be analyzed in this way and, moreover, to be controllable in full measure. This fact may be the reason for the "transformations in the order of time" [17]: ". . . a new time order began to evolve in which the notion of *becoming* dominated over that of *being*". Prigogine called this transformation by "*the rediscovery of tim*e" [18]. The problem which we have to face is a very complex one, and implies a deep conceptual change, which is going on at present. Prigogine pointed out the key role of probability and irreversibility in our conception of the Universe. What is emphasized is that the precise time of elementary processes is determined by chance. In other words, the basic problem is the controversial situation between the static description proposed by classical physics, based on deterministic and time-reversible laws, and the world as we know it, which for sure includes probability as well as irreversibility as basic elements [18].

Mainzer in his influencing book *Thinking in Complexity* [19] has demonstrated that the theory of nonlinear, complex systems has become by now a proven problem-solving approach in the natural sciences. It was also recognized that many, if not most, of our social, ecological, economical and political problems are essentially of a global, complex and nonlinear nature. And it was now further accepted than any holistic perspective of the human mind and brain can hardly be achieved by any other approach. Mainzer presented wide-ranging, scholarly but very concise treatment and discussed lucidly the common framework behind these ideas and challenges. Emphasis was given to the evolution of new structures in natural and cultural systems. He shown clearly how the new integrative approach can give insights not available from traditional reductionistic methods.

1.3 In the Beginning was Action

The theological approach to the time was essentially concerned with the searches for purpose in the Universe [95, 96] as well as for the meaning and purpose of life [97–99]. There is an ill-disposed form to answer about theological approach to time. According to that answer: "Time is God's way of keeping things from happening all at once".
The bulk of this short section will then be a brief analysis of the extensive discussions in literature to respond to fundamental questions about the complementarity of the biblical and scientific understanding of the concept of time and interrelation of science and religion [88–90, 100–103].
The fundamental study [26] summarized the achievements of the ontological approach to the problem of time. To understand the role of time within the scope of 20-th century ontology, after the fundamental works of E. Husserl, M. Heidegger, P. Ricoeur, and others, means to develop simultaneously the ontology of time. Author's aim was to demonstrate that in a definite sense the post-modern ontology is *chronology.* The argument proceeds (and this constitutes its essential novelty) within the 'multidimensional space' involving not only the synchronic stratum of current conceptuality in its internal logical relationships, but also the diachronic axis of conceptual genesis. Author applied different strategies of analysis in order to emphasize that the concept of the human Self, the concept of being, and the concept of time are inseparably linked with one another. To this triad author added one more link of a theological nature, viz. the relationship between God and the human mind as it has been developed in Orthodox apophatic theology and during the Scholastic controversies concerning the problem of *visio Dei.*
Polkinghorne [63] argued lucidly that the characters of space, time, and causality are issues that are constrained by physics but that require also acts of metaphysical decision. Relativity theory is consistent both with the idea of an atemporal block universe and with a temporal universe of true becoming. Science's account of causal properties is patchy and does not imply the closure of the universe to other forms of causal influence. Intrinsic unpredictabilities offer opportunities for metaphysical conjecture concerning the form that such additional causal principles might take. Physics constrains metaphysics but does not determine it. Different theological understandings of how God relates to time afford legitimate criteria for differing metaphysical decisions about the nature of temporality [6].
The Bible contains no abstract philosophy of time as the universal measure of movement such as we find in Greek philosophy [100, 104]. The Hebrew

and Greek words which are translated *time* indicate a *point of time*, and the point is identified by the event which is associated with it. The biblical conception of time is governed by the thought that time is ordered by succession of events which are expected in due time. It is of interest to mention that the theory of information [105] states that at any one point in time a bit can either represent a 0 or a 1, never both.

The Christian theology states [104, 106] that it is God from whom and through whom all things come into being, and to whom all things tend. God has made the world through His Son, who bears all things through His powerful Word.

In this context it is worth to remind the key concept of physics, the *action*. Action is the movement using force or power for some purpose, i.e. **doing things**; the way in which a body moves. This eminently clear, terse, and spirited summary forces us to remember the first verses of *The Book of Genesis* [98, 99, 104]. Indeed, theology formulated [104, 107] the essence of that book as: "...the world was created by the Word, and this transforms the reality. The Word of God forms that world and to become *formative action* for the reality." This approach interprets Genesis as a proclamation of God's decisive *dealing* with creation rather than as history of myth [104]. It is evidently that this meaning of the *action* has something in common with the concept of action in mechanics. In this context it is worth mentioning that the action is one of the key concepts in classical and quantum mechanics and in physics taken as a whole [108–112]. However, the concept of action was somewhat in shadow of other great concepts, such as force, energy, power, work, time, space, etc. There was an impression that the action is, to some extent, an enigmatic notion, because of its intimated interconnection with the notion of time. Indeed, such interconnection exists and deserves a meticulous attention [45, 113].

The notion of the action was invented by Leibnitz about 1699. He denominated this quantity by *actio formalis*, i.e. *formative action*. He wrote this quantity as the production of mass m, velocity v and the length of path s: $\mathcal{A}_M = m \cdot v \cdot s$. Since $s = vt$ this expression is equal to $\mathcal{A}_M = 2E_{\text{kin}} \cdot t$. We denoted the Maupertuis action by $\mathcal{A}_M$ to distinguish it from the Hamilton action $\mathcal{A}_H$ [114, 115].

Formally, action is an integral $\mathcal{A}$ associated with the trajectory of a system in configuration space, equal to the sum of the integrals of the generalized momenta of the system over their canonically conjugate coordinates [109, 110]. This is generally known as the action integral [110]. This terminology does not accord with the original, in which the term *action* was

used for a related but different quantity (the integral of twice the kinetic energy), which is relatively little used [110]. However, it is more convenient, and has now become standard practice, to use this simple name for the commonly occurring function, the action integral [110].
The recognition of the scientific validity of the concept of action is connected closely with the fundamental law of physics, the principle of least action formulated by Maupertuis and Euler. The predecessor of that principle was the postulate by Pierre de Fermat, who supposed that *light travels between two given points along the path of shortest time*, which is known as the principle of least time or Fermat's principle. The principle of least time can be written as (in modern notation): $\int ds/v = \min$. Note, that it was Euler who replaced the path s by the element of the path ds when considered variational problem. Maupertuis (1698-1759) invented the principle of least action [116] as a development of Leibnitz ideas: $mvs = \min$. This version is known as Maupertuis' principle [117–122, 129] - an integral equation that determines the path followed by a physical system. What is of importance is that Maupertuis proposed the principle of least action as a metaphysical principle that underlies all the laws of mechanics. The principle of least action states that in all natural phenomena a quantity called *action* tends to be minimized [117, 131]. Maupertuis [116], formulated it in the following words:

> *Nature, in the production of its effects, does so always by simplest means.*

It must be stressed that for the optical phenomena the quantity which should have a minimum in concrete conditions is the *time.* Hence, what should be done, it is to arrange a possibility for measurement of time's intervals and to establish the relations for it: equal, more than, less than.
On the contrary, mechanical problems differ substantially from the optical problems. Indeed, it is not obvious which quantity should have the extremum (min or max). As Leibnitz and Maupertuis showed, this quantity is quite nontrivial. It is the *action.*
For Maupertuis, *action* could be expressed mathematically as the product of the mass of the body involved, the distance it had travelled and the velocity at which it was travelling. He showed that a system of bodies at rest tends to reach a position in which any change would create the smallest possible change in a quantity that he argued could be assimilated to *action.* The beauty of his principle of least action was that it applied just as well to hard and elastic bodies. Since he had shown that the principle

also applied to systems of bodies at rest and to light, it seemed that it was truly universal.
Maupertuis admitted that the major arguments advanced to prove God, from the wonders of nature or the apparent regularity of the universe are all open to objection. But an universal principle of wisdom provides an *undeniable proof* of the shaping of the universe by a wise Creator.
An interesting analysis of principle of least action was carried out by Mach [108]. According to Mach [108], "Maupertuis enunciated, in 1747, a principle, which he called the principle of least action. He declared this principle to be one which eminently accorded with the wisdom of the Creator. He took as the measure of the *action* the product of the mass, the velocity, and the space described, or *mvs*. Why, it must be confessed, is not clear. By mass and velocity definite quantities may be understood; not so, however, by space, **when the time is not stated** in which the space is described. If, however, unit of time be meant, the distinction of space and velocity in the examples treated by Maupertuis is, to say the least, peculiar. It appears that Maupertuis reached this obscure expression by an unclear mingling of his ideas of *vis viva* and the principle of virtual velocities. Its indistinctness will be more saliently displayed by the details . . . the inference from Maupertuis's deduction is that the principle of least action is fulfilled only in the case of equilibrium, a conclusion which it was certainly not the author intention to demonstrate".
Hence the principle of least (stationary) action is indeed the leading and workable principle when applied to the action of a mechanical and other systems [117, 131, 134]. It can be used to obtain the equations of motion for that system. It should be named more precisely by the *principle of stationary action* [108–110]. It was historically called *least* because its solution requires finding the path of motion in space that has the least value [110]. However from the mathematical point of view the correct term should be *critical*, instead of stationary [115]. The principle can be used to derive Newtonian, Lagrangian and Hamiltonian equations of motion, and even general relativity (e.g. Einstein-Hilbert action). In relativity, a different action must be minimized or maximized.
Indeed, in the simplest case the action of a free particle, which travel from zero coordinate position to the point $\mathbf{r}$ during the time t can be written as:

$$\mathcal{A} = -Et + \mathbf{p} \cdot \mathbf{r}. \tag{1.1}$$

When the free particle is in rest, then the action takes the form

$$\mathcal{A} = -E_0 t = -mc^2 t. \tag{1.2}$$

Here E_0 is the energy in rest and c is the velocity of light. It is also well known that the solution of the wave equation may be written as [131–136]

$$\Psi \sim \exp\left(\frac{i\mathcal{A}}{\hbar}\right). \tag{1.3}$$

Here $\exp\left(i\mathcal{A}/\hbar\right)$ is the amplitude and $\mathcal{A}$ is the action for the path. The phase of the amplitude is a complex number [131, 132]; the phase angle is $\mathcal{A}/\hbar$. The action $\mathcal{A}$ has dimensions of energy times time. The Planck's constant $\hbar$ has the identical dimensions, hence $\mathcal{A}/\hbar$ is dimensionless.

The advanced variational principle was formulated as the Hamilton's principle (named after the mathematician W. R. Hamilton (1805-1865)). It states that the action integral $\mathcal{A}_H$ is stationary under arbitrary variations δx, δy, δz which vanish at the limits of integration t_0 and t_1. The importance of this principle lies in the fact that it can immediately be applied to any set of co-ordinates. The Hamilton action principle [114, 115, 117, 137] compares the numerical value of the action $\mathcal{A}_H$ along the actual worldline to its value along every adjacent curve, i.e. trial worldline, corresponded to the same initial and final events.

In this way it is possible to derive the Lagrange's equations. Lagrange's equations are of great importance in advanced treatments of classical mechanics (and also in quantum mechanics). They can be used to write down equations of motion in any system of coordinates, as soon as we have found the expressions for the kinetic energy and potential energy. It is interesting to note that the Maupertuis's and Hamilton's principles of least action are recognized as the major theoretical principles of physical science; it still persuade to metaphysical debate on their essence and value [138]. To summarize, Maupertuis conjectured that, whenever there is a change in nature, the quantity of action necessary for this change is the least possible. Euler, using variational methods, presented principle of least action as a theorem of dynamics for a single particle and Lagrange generalized Euler's definition for a system of mutually interacting particles. Finally, Hamilton introduced Hamilton's principle, a variational principle that applies to all physical systems whose dynamics is governed by a potential energy function [117, 118, 138].

The action takes different values when the system follows different possible paths in its configuration space. According to Hamilton's principle [118, 138], the physical system should actually follow the path which makes the action stationary: $\delta\mathcal{A}_H = 0$. The variation δ is not arbitrary since all possible paths in configuration space should terminate at end points representing the system configuration at the same time t_1 and t_2 as the actual

path.
And last but not least remark will be not out of place here in the context of the action and time. It should be stressed that time is the form of our sentient being; we know no other. Indeed, language as the human method of communication of knowledge, ideas, feeling, etc., sues a system of sound (or other) symbols. Language thus implies in a deepest sense the notion of time. Time is an inherent component of grammatical structure and is the immanent quality of language [139, 140]. A grammar is impossible without verbs and starts with a definition what a verb is. Verb is a word showing what a person or thing does, what state he or it is in, or what is becoming of him or it. According to context, verbs can be described as words denoting action. The term "action" embraces the meaning of activity, process, relation, etc. Action is the process of doing things. It is a way of using energy, influence, etc. The expression "the time has come for action" means a signal to begin to act. English verbs fall into two groups: the *dynamic* verbs and the *stative* verbs [139, 140]. The distinction between dynamic and stative verbs is a fundamental one in English grammar; it divides the verbs into two groups, i.e. those which admit of the continuous form and verbs which do not admit. It is normal for verbs to be dynamic. Tense is the form of the verb which indicates the *time of the action.* Thus the time is unavoidable essence of the language and our mental being!

1.4 The Phenomenon of Time

The studies of phenomenon of time and temporality from various sides (physics, chemistry, biology, cosmology) start to develop intensely from the second half of 20-th century [141]. When considering a perspective on the history of physics over the past four hundreds years, it is become evident that there were the mainstream topics of investigations in each century. Time studies began to increase in the last two centuries [141, 142]. The history of physics [143–151] and the history of theoretical physics [152–155] show that the studies on time were stimulated in part by intensive researches of space and accelerating development of astrophysics and cosmology in 20-th and 21-th centuries. A common thread across the numerous studies on the history of physics [147, 152–155] is the search for and the exploration of themes that influenced significant conceptual changes in the development of leading ideas which directed the emergence of new streams and experimental efforts [143, 146, 147, 152, 153]. These fundamental changes involved the recognition of the scientific validity of theoretical physics [152] and showed its operational ability and conceptual value.

Table 1.1 Basic Themes of Physics.

Century	Themes	Persons
17	Kinematics, Optics, Telescope, Clock	Galilei, Kepler, Huygens, Newton
18	Aether, Dynamics, Force, Optics	Newton, Leibnitz, Laplace, Young
19	Energy, Entropy, Fields, Electron	Faraday, Maxwell, Helmholtz, Planck
20	Quantum, Gravitation, Interactions	Planck, Bohr, Einstein, Lemaitre, Higgs
21	Action, Time, Cosmology, Life	Prigogine, Penrose, Guth, Haken, Eigen

We summarized the mainstream topics in an approximate and schematic way in the Table 1.1

The arguments formulated above prove the necessity of the discussion and careful reconsideration of the problem of time and temporality from a broad perspective in the context of natural processes. And the first of the all processes is the passage of the physical time.

Cushing in his book [84] examined a selection of philosophical issues in the context of specific episodes in the development of physical theories. Advances in science were presented against the historical and philosophical backgrounds in which they occurred. A major aim was to impress upon the reader the essential role that philosophical considerations have played in the actual practice of science. The book begins with some necessary introduction to the history of ancient and early modern science, with major emphasis being given to the two great watersheds of twentieth-century physics: relativity and, especially, quantum mechanics. At times the term 'construction' may seem more appropriate than 'discovery' for the way theories have developed and, especially in the later chapters, the question of the influence of historical, philosophical and even social factors on the very form and content of scientific theories was discussed lucidly (see also Refs. [91–93]).

Wilcox [94] advocates the peaceful and complementary value of a strong biblical faith and to faithful, responsible science. He maintains that there can be no conflict between Scripture and the natural world because God is the author of both. The contentious debate over evolution is a result of a failure to recognize and respect the *boundaries of science* and also the boundaries of theology. The author addresses such topics as the age of the earth and the origins of life, including human life, exploring from a scientist's perspective what we know and how we know it. His objective was to help us reach a point in their faith where they do not have to choose between God and science, but where they can embrace science as a part of the divine plan.

Davies re-examined the great questions of existence and and the possibility of penetrating into the divine plan in the context of recent developments in theoretical physics [170]. Throughout history, humans have tried to find the reason for the existence of the universe. Davies explored [170] whether modern science can provide the key that will unlock this last secret. In his quest for an ultimate explanation, Davies reexamines the great questions that have preoccupied humankind for millennia, and in the process explores, among other topics, the origin and evolution of the cosmos, the nature of life and consciousness, and the claim that our universe is a kind of gigantic computer. Davies discussed the ways in which the theories of such scientists as Newton, Einstein, and more recently Stephen Hawking and Richard Feynman have altered our conception of the physical universe. Davies puts these scientific achievements into context with the writings of philosophers such as Plato, Descartes, Hume, and Kant. His startling conclusion is that the universe is "no minor byproduct of mindless, purposeless forces. We are truly meant to be here." By the means of science, we can really penetrate in part into the "mind of God".

McGrath in his book [171] "Inventing the Universe: Why we can't stop talking about science, faith and God" formulated a balanced approach for reconciliation between the science and religion. He put the question: Does profound disagreement on the 'big questions' of origins, proof, the meaning of life and our place in the universe mean that faith and science must be constantly at war?

McGrath discusses the opinion of many writers on the subject from Augustine right through to the present day. He argues for a "multi-layered" understanding of reality, holding science's discoveries at the same time as religion's view of reality. He shows that both worldviews can coexist peacefully and shares his personal journey to a faith enriched by scientific understanding; identifies errors in atheists' criticism of religion; and suggests that even apparently irreconcilable views about Darwinism can be mutually enriching.

Complementary plausible arguments for a realistic conception of temporal process and for God's involvement in the temporal distinctions and processes because of His presence in His creation were formulated by Craig [172–176] and by Heller [96]. In particular, Craig discusses the coherent doctrine of divine eternity and God's relationship to time. Heller [96] examines how far our modern cosmological theories - with their sometimes audacious models, such as inflation, cyclic histories, quantum creation, parallel universes - can take us towards answering the fundamental questions. Can such theories lead us to ultimate truths, leaving nothing unexplained? Last, but not least, Heller addresses the thorny problem of why and whether we should expect to find theories with all-encompassing explicative power.

1.5 Biography of Stanley L. Jaki

Father Professor Stanley L. Jaki OSB[1] (June 10, 1924 - April 07, 2009) was Catholic priest and physicist as well as a distinguished historian and philosopher of science.
Father Jaki was a Distinguished Professor of Physics at Seton Hall University, New Jersey. He was a leading thinker in philosophy of science, theology and on issues where the two disciplines meet and diverge.
He entered the Benedictine Order in 1942, and began studies in philosophy, theology, and mathematics. In 1947 he went to Rome, where he continued theological study at the Pontifical Institute of San Anselmo and gained his doctorate (1950). He was ordained in 1948. During 1954-8 he studied physics. After completing undergraduate training in philosophy, theology and mathematics, Father Jaki did graduate work in theology and physics and holds doctorates in theology from the Pontifical Institute in Rome (1950), and in physics from Fordham University (1958). He also did post-doctoral research in Philosophy of Science at Stanford University, University of California, Berkeley, Princeton University and Institute for Advanced Study, Princeton. After post-doctoral research, Father Jaki was Gifford Lecturer at Edinburgh University(1974-76), Fremantle Lecturer at Balliol College, Oxford(1977), Hoyt Fellow at Yale University(1980) and Farmington Institute Lecturer at Oxford University(1988-1989). After 1965 was professor of astrophysics at Seton Hall University, NJ, USA.
Noted as a leading writer on interdisciplinary studies in the areas of science and theology, he was honorary member of the Pontifical Academy of Science, and the recipient of the Lecomte du Nouy Prize (1970) and the Templeton Prize for Progress in Religion and for furthering understanding of science and religion(1987).
His Bibliography consists of about 200 items. Father Jaki was a famous writer and was the author of more than 40 books on the differences and

[1] http://theor.jinr.ru/˜kuzemsky/sljkbio.html

similarities between science and religion. Dr. Jaki was the author of numerous books, articles, reviews, and lectures.
He was the first person to recognize the significance of Godel's Theorem for 'theories of everything (TOE)" in theoretical physics. Godel's theorem states that any non-trivial mathematical theory will be either incomplete or inconsistent. Since any 'theory of everything' will certainly be a non-trivial mathematical theory, it must be either incomplete or inconsistent, thus dooming searches for a theory of everything in which all the parameters are defined internally and consistently.
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