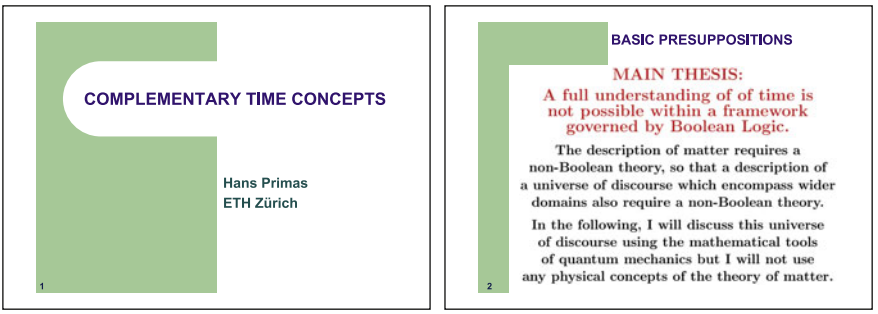
Editor's Preface

When Hans Primas died in October 2014 at age 86, he left behind an extensive manuscript on which he had worked for the last five years of his life. It addressed two main topics: first, *knowledge* and the different ways it can be acquired, and second, the role that different notions of *time* play in knowledge acquisition, creatively and rationally. The fields of human scholarship that he touches upon during this challenging journey in thirteen chapters culminate in a proposal for a new understanding of the relationship between the mental and the physical—one of the oldest unsolved mysteries in both science and philosophy.

The key tools he uses in his wide-ranging explorations are concepts such as complementarity and entanglement, and the logic of partial Boolean algebras—all well known to be at the heart of modern quantum physics. However, Primas applies them not only to physics problems. This positions his work in the tradition of Niels Bohr, Wolfgang Pauli and others, who were always convinced that the mathematical structures underlying quantum theory are significant and viable far beyond the limits of quantum physics.

Primas was interested in time from various viewpoints and for many years, for instance in the role of time in dynamical models of measurement in quantum physics. Yet his first publication explicitly discussing time in the context of the mind-matter problem appeared only in 2003: "Time-Entanglement Between Mind and Matter" (Primas 2003). Several years later he published a refined version of that article as "Complementarity of Mind and Matter" (Primas 2009).

In both articles he argued that a more profound understanding of the many facets of time could be useful for our conceptions of the mental, the physical, and their relationship—even more so since our experience of time and the physical concept of time are radically different, despite having important features in common. The philosophical perspective that he proposed falls into the class of *dual-aspect* approaches, in which the mental and the physical are neither substances on their own (as in Cartesian dualism) nor are they reducible to one another (as in physicalist or idealist frameworks). Rather, they are considered as two aspects, as it were, of one underlying "neutral" domain that itself has no mind-matter distinction.



The first two slides of the presentation that Hans Primas gave at a workshop of the Parmenides Foundation in Munich in April 2010

Shortly after his 2009 paper had appeared, Primas began drafting first versions of a manuscript more comprehensive than the two precursor publications. At about the same time he was invited to give a presentation at a workshop about "the forgotten present" of the Parmenides Foundation in Munich in the spring of 2010. This presentation was based on his ideas about various perspectives on time at that juncture. Its slides are available online[*] and may serve as a quick guide to what the reader can expect from Part II (on time) of the more elaborate and more sophisticated material contained in this final monograph.

With one major interruption due to serious health problems in 2011, Primas worked continuously on the manuscript right up until his death in 2014. His latest adjustment was a reorganization of the material on bottom-up and top-down theories in physics, two sections that now conclude Part I (on knowledge) of the monograph in its present form. They outline his highly original account of how to understand the structure and development of our knowledge about the physical world—with a pronounced focus on quantum theory.

Since I was in constant contact with Hans Primas over the preceding two decades, it is likely that I am more familiar than anyone else with the intentions and the themes of his work and his ways of thinking in these years. So it came as no great surprise to me when his family asked me to examine the manuscript and come to a decision about whether and how it could be brought to the attention of an audience for which it would be of interest. It was evident to me from the outset that there is undoubtedly such an audience. Hence, the actual question was whether the material was prepared well enough to permit an editing process leading to its coherent exposition.

According to first-hand information from his family, Primas, in his last days, had considered the manuscript as essentially complete but largely unedited. What

[*]The slides of his presentation can be downloaded at www.parmenides-foundation.org/fileadmin/redakteure/events/PW_19/Hans_Primas.pdf. Primas did not submit a manuscript for the proceedings of the workshop, which later appeared as "Re-Thinking Time at the Interface of Physics and Philosophy" (von Müller and Filk 2015), but obviously the feedback he received at the workshop inspired him to work out his ideas to much greater depth.

needed to be done first was to retrieve the relevant files from his computer and locate those which contained the most recent, finished version of each section. It soon turned out that the overall manuscript was in a state ready for editing, but it was also clear early on that this would be a job far less straightforward than editing typical collections of essays or journal issues. With some unavoidable intermissions, it took about 18 months of work from the first steps in the process to the submission of the final manuscript for publication.

The style of the text will not surprise anyone who knows the monograph that Primas had published 35 years earlier on "Chemistry, Quantum Mechanics, and Reductionism" (Primas 1981). The present book is again a composition of pivotal conceptual insights, quotes that illustrate important points, critical remarks about misunderstandings in the literature, the subtle mathematics of algebraic quantum theory, detailed knowledge about engineering and systems theory. It exhibits the personality of a scholar who combines deep foundational interests, formidable mathematical skills, and exceptionally broad scientific and engineering background in a unique way.

Last but not least, the book reflects a respectful appreciation of the groundbreaking work by pioneers such as Araki, Bohr, Connes, Dirac, Einstein, Gödel, Haag, Hertz, Holevo, Kolmogorov, Ludwig, Pauli, Poincaré, Strauss, von Neumann, Weyl, Wiener, and Wigner. This list highlights just the most frequent authors in a bibliography of more than 1000 references. As a special service, readers will find, together with each reference in the bibliography, the particular section(s) in the monograph where it is referred to.

Among the extensive appendices that Primas added for further details and background, only the one about algebras of observables was retained in the published book. It contains many important results whose compact and succinct presentation is hard to find in the standard literature. Other appendices, presenting material about stochastic processes, harmonic analysis, fluctuation-dissipation theorems, etc. have been dropped since there are good reviews or textbooks that can easily be consulted about them.

The text contains several long passages with illustrative engineering examples, for instance detailed discussions of various kinds of filters in Chaps. 3 and 12. Although one might have regarded these as digressions, they were retained because engineering examples are so typical of Primas' way of illustrating his ideas. Moreover, readers will notice his often meticulous mathematical notation, for instance his insistence on specifying the domain of variables (e.g., $t \in \mathbb{R}$) or the expression of functions as $t \to f(t)$ rather than simply $f(t)$. This has become somewhat unusual in standard textbooks, but it is an integral part of Primas' style of presentation, and so it, too, was left untouched in the editing process.

As sketched above, "Knowledge and Time" consists of two parts, the first entitled *Knowledge*, the second *Time*.[**] Part I begins with introductory remarks about why

[**]Insiders will realize that a book with almost the same title exists in German language: "Zeit und Wissen" (Time and Knowledge) by the late Carl Friedrich von Weizsäcker (1992). Though its content and style are very different from the present book, the title testifies that Primas and

a proper understanding of time cannot be achieved within a Boolean framework of thinking (compare the "main thesis" on the second slide on page viii above) as it underlies virtually all of classical science. Chapters 2 and 3 outline the nature of Boolean versus non-Boolean descriptions. While a Boolean two-valued logic with truth values "true" and "false" is best characterized by the famous "rule of the excluded middle" (or *tertium non datur*), non-Boolean logic violates this rule. The consequence is incompatible descriptions, which are central to the notion of *complementarity*. Originally imported into quantum physics by Bohr, complementary descriptions are formally related to *non-commutative algebras of observables*.

Chapter 4 addresses creativity and rationality or, more precisely, creative insight and its rational reconstruction, two complementary modes of knowledge, as Primas puts it, that are both needed for sound and innovative scientific progress. He relates them to two complementary modes of *non-sequential* and *sequential* processing, which will become the prototypes for non-sequential and sequential time in Part II. Chapter 5 discusses numerous examples of creativity and rationality in mathematical knowledge, for instance the extraordinary insights of the mathematician Ramanujan and the seminal contributions by the logician Kurt Gödel. Part I ends with Primas' account of quantum theory considered in terms of the familiar bottom-up approach (Chap. 6) as contrasted with a less discussed top-down point of view (Chap. 7).

Ultimately, the message of Chaps. 6 and 7 is that both top-down and bottom-up thinking are needed in combination, such as in the proverbial phrase "it's top down all the way from the bottom up". Remarkably, the two directions "up" and "down" may be considered as indicating two different versions of *emergence*—a concept that plays an important role in Primas' work. The traditional bottom-up type of emergence describes how irreducible higher-level properties can be understood to arise from lower-level properties. On the other hand, top-down emergence typically is based on restrictions and resulting symmetry breakings that a higher level imposes on lower levels.

Chapter 8, the first section in Part II, ought to be seen as the conceptual core of "Knowledge and Time". Based on the observation that time as such is neither mental nor material, Primas posits a tripartite structure of the total universe of discourse with a temporal domain, an atemporal mental domain, and an atemporal material domain. Assuming that these domains are non-Boolean, they are holistically correlated, very much in the spirit of quantum *entanglement*. If all three of them are holistically correlated, any strict distinction between time, mind and matter gets lost, and we regain the idea of an undivided universe for which Primas (2003, 2009) used the term *unus mundus* in his earlier publications on the subject.[***] Bilateral correlations between the mental and the material yield mind-matter correlations, and

von Weizsäcker shared a common view on the philosophical foundations of science, which they frequently discussed when they met.

[***]The notion of an *unus mundus* in this sense derives from the dual-aspect framework of thinking that Pauli and Jung developed in the mid-20th century (cf. Atmanspacher 2012 for details). Interestingly, Primas' original manuscript files do not mention the term *unus mundus*, nor does he tell his readers how it is replaced or, more to the point, generalized.

bilateral correlations between each of these two domains and the temporal domain introduce mental (psychological) and material (physical) time.

Subsequently, Primas unpacks his technical repertoire on group theory and algebras of observables by introducing and employing temporal groups and algebras, their representations, and corresponding descriptions of temporal phenomena. Of major relevance for the notions of sequential and non-sequential time are the affine time group and the affine frequency group (Chap. 9), which can be realized by time and frequency operators referring to past and future as well as positive and negative frequencies, respectively. They generate four semigroups, whose representations (for simplicity in Hilbert space) are addressed in Chap. 10, with particular emphasis on the representation of temporal states. In Chap. 11, the complementarity of sequential and non-sequential semigroups in the time and frequency domains is further elaborated. Examples of temporal distributions, expressing states that are extended in time, are indicated.

For the non-expert, these sections will be hard to follow, but they are related to an important conceptual lesson that Primas discovered in his study of algebraic quantum theory in the late 1980s (see Primas 1990a). The distinction between algebras of observables and their (contextual) representation reflects a crucial difference between *ontic and epistemic interpretations* of the properties of a system as they are formalized by observables. While ontic frameworks typically exhibit high degrees of symmetry (and corresponding formal simplicity and transparency), epistemic frameworks require broken symmetries in order to describe the multitude and complexity of properties in the world of empirical facts. Chapters 9–11 adopt this insight with respect to temporal structures.

The concluding chapters of "Knowledge and Time" are devoted to the *relevance* of sequential and non-sequential time, respectively. Sequential time is the time concept mostly used in the sciences, a parameter time measuring the temporal distance between facts with a clock (Chap. 12). But the apparently simple question of how facts are generated already leads to severe challenges that to date have not been uncontroversially resolved. In any event, once there are facts, they can be causally ordered, and experiments can be causally described. Most issues related to determinism, causation, prediction and retrodiction in science are based on sequential time.

By contrast, non-sequential time is not, or only rarely, addressed in the sciences at all. Chapter 13 lays out some ideas about how it might acquire significance in both mental and physical contexts. On the mental side, the experienced duration of the present is a key issue, which has been much studied in psychology, cognitive science, and the phenomenological tradition of philosophy. From the perspective of physics, related phenomena have been occasionally referred to by the notion of temporal nonlocality or temporal entanglement. Very recent developments linked to the investigation of such phenomena are sketched at the end of the section.

Although the monograph is arranged linearly by necessity, the thoughtful reader will notice that particular key topics re-appear in different contexts, leading to a gradual strengthening of their significance. These repetitive themes are partial Boolean algebras, the notions of complementarity and entanglement, and the contrast between different kinds of knowledge processing. First introduced formally

and by examples, they arise again in the way they are used in quantum physics, and eventually are exploited for the discussion of the complementary modes of sequential and non-sequential time. In this way, the subtle layers of "Knowledge and Time" unveil themselves step by step, like the petals of a flower opening up slowly to finally reveal its full beauty.

Given the mathematical sophistication of much of the text, it is clear that the book is not exactly an "easy read". However, it offers such innovative and far-reaching concepts, so much stimulation and inspiration, and so many promising ideas deserving further studies that it truly would have been a shame to leave all this publicly unrecognized. So here it is, and—as always—there are some acknowledgments to be made for the support and encouragement received during the editorial work.

Major thanks go to Margarita Primas, who carefully checked and approved all corrections and editorial changes implemented in the manuscript, and who was of substantial help in the preparation of the bibliography and the index. All additions that clearly go beyond the original text are marked as editor's notes in the text. Mostly, this concerns updates on certain topics with recent literature, or simply translations of non-English quotations into English.

Thomas Filk double-checked Sect. 7.3 on local quantum physics and provided advice on how to redesign parts of the formalism to make sure that the ideas are easier to follow by readers used to standard textbook presentations. And, finally, Angela Lahee at Springer and some referees she consulted for the manuscript accompanied the publication process with professional courtesy and with the insight that such a monograph requires to be broadly accessible.

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