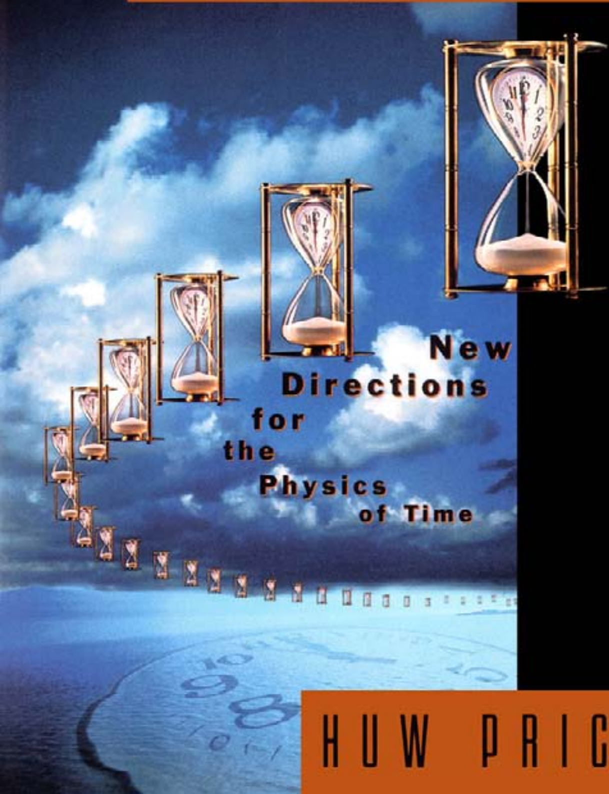
Time's Arrow and Archimedes' Point



New Directions for the Physics of Time

HUW PRICE

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NEW DIRECTIONS FOR THE PHYSICS OF TIME

Huw Price

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Preface

Time flies like an arrow; fruit flies like a banana.
MARX.

SCIENCE, like comedy, often demands that we look at familiar things in unfamiliar ways. Miss the new angles, and we miss the point. In comedy it is the comic's job to pitch the task at the right level. Too low, and the joke isn't funny; too high, and the audience doesn't get it. In science, of course, we are on our own. There are no guarantees that Nature's gags have been pitched within reach. Great scientists spend lifetimes trying to nut out the hard ones.

This book is about one of these perspective shifts—about the need to look at a familiar subject matter from a new vantage point. The subject matter concerned is one of the most familiar of all: it is time, and especially the direction of time. Despite its familiarity, time remains profoundly puzzling. It puzzles contemporary physicists and philosophers who spend large amounts of it thinking about it, as well as countless reflective nonspecialists, in search of a deeper understanding of one of the most central aspects of human life.

This book is about the need to think about time's puzzles from a new viewpoint, a viewpoint *outside* time. One of my main themes is that physicists and philosophers tend to think about time from too close up. We ourselves are creatures in time, and this is reflected in many ordinary ways of thinking and talking about the world. This makes it very difficult to think about time in an objective way, because it is always difficult to tell whether what we think we see is just a product of our vantage point. In effect, we are too close to the subject matter to see it objectively, and need to step back.

This a familiar idea in the history of science. For example, it took our ancestors a long time to figure out that the Earth and a pebble are the same kind of thing, differing only in size. To take this revolutionary idea on board, one needs to imagine a vantage point from which the Earth and the pebble can both be seen for what they are. Archimedes went one better, and offered to move the Earth, if someone would supply him with this vantage point, and a suitable lever.

I want to show that a temporal version of this Archimedean vantage point provides important insights into some of the old puzzles about time. One of its most useful roles is to highlight some old and persistent mistakes that physicists tend to make when they think about the direction of time. More surprisingly, this viewpoint also has important benefits elsewhere in physics. In particular, it throws some fascinating new light on the bizarre puzzles of quantum mechanics. Thus the book offers a novel approach to some of the most engaging issues in contemporary physics, as well as a new perspective on some of the familiar puzzles of time itself.

The book is addressed to interested nonspecialists, as well as to physicists and philosophers. In part, this is a kind of fortunate accident. My original thought was to try to make the book accessible to physicists as well as to philosophers (my home team). Many of its conclusions were going to be aimed at physicists, and I realized that there was no point in writing a book that much of the intended audience could not understand. At the same time, however, I wanted the book to be interesting and useful to my philosophical colleagues and students, most of whom have no training in physics. So I aimed for a book which would be accessible to physicists with no training in philosophy and to philosophers with no training in physics. The happy result, I think, is a book which will interest many people whose formal education qualifies on both counts: no philosophy *and* no physics.

I've been thinking about these things for a long time. As an undergraduate at ANU, Canberra, in the mid-1970s, the philosophy of time played a large part in my decision to abandon mathematics for philosophy. (I had the good fortune to encounter, in person, the very different perspectives on time of Genevieve Lloyd and Hugh Mellor.) I was an almost instant convert to the atemporal "block universe" view of time (described in chapter 1), at least for the purposes of physics. This view remains the key to the argument of the whole book.

A couple of years after that, I was already thinking about some of the issues about physics that turn up later in the book. I remember listening to a discussion of Bell's Theorem and quantum mechanics at a philosophy seminar in Oxford, and being struck by the thought that one of its crucial assumptions was time-asymmetric, in a way which looks very odd from the kind of atemporal viewpoint that goes with the block universe view. I think that I was right, but the issue turned out to be much more complicated than I then imagined, and it has taken a long time to disentangle all the threads. Strangely, one of the crucial threads goes back to the work of Michael Dummett, the Oxford philosopher who was the speaker that day in 1977—though his topic had nothing to do with the relevant part of his earlier work, as far as I can recall.

A couple of years later again, now a graduate student in Cambridge, I learned more about the physics of time asymmetry. One wet weekend in the spring of 1979, I attended a small conference on the philosophy of time in Barnstable, Devon. One of the invited speakers was Paul Davies, then a young lecturer in theoretical physics at King's College, London, who talked about the latest ideas on time in cosmology. I remember asking him afterwards why cosmologists continued to take for granted that the present state of the universe should be explained in terms of its earlier state, rather than its later state. From the atemporal perspective, I felt, this temporal bias looked rather puzzling. I can't remember exactly what Davies said in reply, but I am sure I failed to convince him that there was anything suspicious going on. But I think the failing wasn't entirely mine: I have learned that even at this level, it isn't unusual for physicists and philosophers to have trouble seeing the in-built temporal asymmetries in the ways we think about the world.

After graduate school, other philosophical projects kept me busy, and for several years I had little time for time. In 1988–1989, however, with another book finished, and a new job in the Research School of Social Sciences at ANU, I was able to pick up the threads. I became increasingly convinced that physicists tended to make serious mistakes when they thought about time, and especially about the direction of time—the kind of mistakes that careful philosophical thought could help to set right. And the underlying cause of most of these mistakes, I felt, was a failure to look at the problems from a sufficiently distant vantage point. Thus the basic project of the book was laid down.

I moved to the University of Sydney in the (southern) winter of 1989. Since then, in trying to extract the book from the gaps between other projects and responsibilities, I have been much assisted by research funding from the University's Research Grant Scheme (1991) and the Australian Research Council (1992–1993). I have also learned a lot from my students. For several years I have tried out these ideas on mixed classes of advanced undergraduates in philosophy and physics. Their reactions and comments—especially those of the rather skeptical physicists—have been invaluable in helping me to clarify my views. Among my graduate students, I am grateful to Phillip Hart, Nicholas Smith, and Patrick Yong for their comments, criticism and encouragement; and especially to Phil Dowe, now a colleague, with whom I have had many useful discussions about causal asymmetry and other things.

In the course of this long project, many other people have helped me with comments on drafts, or discussions or correspondence on particular topics. I am variously indebted to David Albert, John Baez, John Bell, Jeremy Butterfield, Craig Callender, David Chalmers, Paul Davies, Jan Faye, John Gribbin, Dan Hausman, Paul Horwich, Raymond Laflamme, Stephen Leeds, John

Leslie, David Lewis, Storrs McCall, Peter Menzies, Graham Nerlich, Graham Oppy, David Papineau, Roger Penrose, Daniel Quesada, Steve Savitt, Jack Smart, Jason Twamley, Robert Weingard, and Dieter Zeh—and, I suspect and fear, to many others whose specific contributions I cannot now recall.

Two of these people deserve special mention. Jack Smart is an Australian philosopher, well known, among other things, for his work on the philosophy of time. (Twenty years ago, when I first encountered the subject, his work was already classic.) Because he is an exponent of the block universe view, as well as a generous and enthusiastic man, I expected him to be positive about the early drafts of this book. Even so, the warmth of his response has surprised me, and his comments and enthusiasm have been a very great source of encouragement.

Dieter Zeh, of Heidelberg University, is well known among physicists for his work on the direction of time. He wrote to me in 1989, responding to an article which had just appeared in *Nature,* in which I criticized some of Stephen Hawking's claims about the direction of time. I felt rather hesitant about taking on such a famous opponent in such a public forum, so it was a great relief and encouragement when Zeh's note arrived, saying "I agree with every word you say about Hawking." We have been regular correspondents since then, and although there are many points on which we continue to disagree, these exchanges have been an important source of insight and encouragement, as the book has come together.

Some of the book draws on material I have previously published elsewhere. Chapter 3 relies heavily on the article listed in the Bibliography as Price (1991c), chapter 4 on (1995), chapter 6 on (1992a), and parts of chapters 7 and 9 on (1994). I am grateful to the editors and publishers concerned for permission to reuse the material in this form.

Finally, two more personal acknowledgments. I am very warmly indebted to Nye Rozea, not least for his cheerful and unflagging skepticism about the entire project—indeed, about my intellectual capacities in general. This proved a priceless antidote to self-esteem, and I'm not sure which of us will be more surprised to see the book finished. Nye's generous filial skepticism was tempered, happily, by the support and enthusiasm—more considered, I think, but perhaps therefore even more generous—of Susan Dodds. To these two friends, then, for what it's worth: take this ...

Contents

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Time's Arrow & Archimedes' Point

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1

The View from Nowhen

SAINT AUGUSTINE (354–430) remarks that time is at once familiar and deeply mysterious. "What is time?" he asks. "If nobody asks me, I know; but if I were desirous to explain it to one that should ask me, plainly I know not."[1] Despite some notable advances in science and philosophy since the late fourth century, time has retained this unusual dual character. Many of the questions that contemporary physicists and philosophers ask about time are still couched in such everyday terms as to be readily comprehensible not only to specialists on both sides of the widening gulf between the two subjects—that in itself is remarkable enough—but also to educated people who know almost nothing about either field. Time is something rather special, then. Few deep issues lie so close to the surface, and fewer still are yet to be claimed by a single academic discipline.

This book is concerned with a particular kind of question about time. What is the difference between the past and the future? Could—and does—the future affect the past? What gives time its direction, or "arrow"? Could time be symmetric, or a universe be symmetric in time? What would such a world be like? Is our world like that? The book is concerned with what modern physics has to say about issues of this kind, but I am not writing as a physicist, explaining the insights of my discipline to a general audience. I am a philosopher, and the vantage point of the book is philosophical. One of my main aims is to sort out some philosophical confusions in the answers that contemporary physicists typically give to these questions. I want to provide physicists themselves, as well as philosophers and general readers, with a clearer picture of these issues than has yet been available.

What are these philosophical confusions? The most basic mistake, I shall be arguing, is that people who think about these problems—philosophers as well as physicists—often fail to pay adequate attention to the temporal character of the viewpoint which we humans have on the world. We are creatures *in* time, and this has a very great effect on how we think *about* time and the temporal aspects of reality. But here, as elsewhere, it is very difficult to distinguish what is genuinely an aspect of reality from what is a kind of appearance, or artifact, of the particular perspective from which we regard reality. I want to show that a distinction of this kind is crucial to the project of understanding the asymmetry of time. In philosophy and in physics, theorists make mistakes which can be traced to a failure to draw the distinction sufficiently clearly.

The need to guard against anthropocentrism of this kind is a familiar theme in the history of both science and philosophy. One of the great projects in the history of modern thought has been the attempt to achieve the untainted perspective, the Archimedean view of reality—"the view from nowhere," as the philosopher Thomas Nagel calls it.[2] The main theme of this book is that neither physics nor philosophy has yet paid enough attention to the temporal aspect of this ancient quest. In particular, I want to show that if we want to understand the asymmetry of time then we need to be able to understand, and quarantine, the various ways in which our patterns of thought reflect the peculiarities of our own temporal perspective. We need to acquaint ourselves with what might aptly be called the view from *nowhen.*

Our interest in questions of temporal asymmetry thus lies at more than one level. There is the intrinsic interest of the physical issues themselves, of course, and the book aims to present a clearer, more insightful, and more accessible view of the main problems and their possible resolutions than has yet been available. In criticizing previous writers, however, my main argument will be that when discussing temporal asymmetry, they have often failed to disentangle the human temporal perspective from the intended subject matter. And it is the asymmetry of our ordinary temporal perspective which is the source of the difficulty, so that the task of unraveling the anthropocentric products of this perspective goes hand in hand with that of deciding how much of temporal asymmetry is really objective, and therefore in need of explanation by physics.

The book thus straddles the territory between physics and philosophy. On the physical side, my main goal will be to obtain a clear view of the problem, or problems, of the asymmetry of time, to correct certain common errors in existing approaches to the problem, and to assess current prospects for a solution. But the main contribution I bring to these problems will be a philosophical one, particularly that of showing how errors arise from a failure to distinguish between the viewpoint we have from within time and the Archimedean standpoint from which physics needs to address these issues. On the purely philosophical side, I shall be interested in the project of characterizing this view from nowhen—of deciding which features of the ordinary world remain visible from this perspective, for example, and which turn out to depend on the temporal viewpoint we normally occupy.

Perspective shifts of this kind are nothing new in science, of course. Some of the most dramatic revolutions in the history of science have been those that have overturned previous conceptions of our own place in nature. The effect is something like that of coming suddenly to a high vantage point—at once exciting and terrifying, as a familiar view of our surroundings is revealed to be a limited and self-centered perspective on a larger but more impersonal reality. In physics the most dramatic example is the Copernican revolution, with its overthrow of the geocentric view of the universe. In biology it is Darwinism, with its implications for the place of humanity in nature. These two examples are linked in the more gradual but almost equally revolutionary discovery of cosmological time (and hence of the insignificance of human history on the cosmological scale).

While the perspective shift I shall be recommending in this book is not in this league—it would be difficult to significantly dehumanize a world in which the place of humanity is already so insignificant—it does have some of their horizon-extending impact. For it turns on the realization that our present view of time and the temporal structure of the world is still constrained and distorted by the contingencies of our viewpoint. Where time itself is concerned, I claim, we haven't yet managed to tease apart what Wilfred Sellars calls the scientific and manifest images—to distinguish how the world *actually is,* from how it *seems to be* from our particular standpoint.

As in earlier cases, the intellectual constraint is largely self-imposed. To notice the new standpoint is to be free to take it up, at least for the purposes of physics. (We can't actually stand outside time, but we can imagine the physics of a creature who could.) Again the discovery is both exciting and unsettling, however, in showing us a less anthropocentric, more objective, but even more impersonal world.

OUTLINE OF THE BOOK

The remainder of this introductory chapter deals with some important preliminaries. One of these is to set aside certain philosophical issues about time which won't be dealt with later in the book. Philosophical discussions of time have often focused on two main issues, that of the objectivity or otherwise of the past-present-future distinction, and that of the status of the flow of time. Philosophers have tended to divide into two camps on these issues. On the one side are those who treat flow and the present as objective features of the world; on the other, those who argue that these things are mere artifacts of our subjective perspective on the world. For most of the book I shall be taking the latter view for granted. (Indeed, I take the central philosophical project of the book to be continuous with that of philosophers such as D. C. Williams, J. J. C. Smart, A. Grünbaum, and D. H. Mellor.)[3] I shall presuppose that we have learnt from this tradition that many of our ordinary temporal notions are anthropocentric in this way. My aim is to extend these insights, and apply them to physics. I shall not defend this presupposition in the sort of detail it receives elsewhere in the philosophical literature—that would take a book to itself—but I set out below what I see as the main points in its favor.

The second important preliminary task is to clarify what is meant by the asymmetry or arrow of time. A significant source of confusion in contemporary work on these topics is that a number of distinct notions and questions are not properly distinguished. It will be important to say in advance what our project is, and to set other issues to one side. Again, however, I shall draw these distinctions rather quickly, with no claim to be philosophically comprehensive, in order to be able to get on with the main project.

With the preliminaries out of the way, the remainder of the book is in two main parts. The first part (chapters 2–4) focuses on the three main areas in which temporal asymmetry turns up in modern physics: in thermodynamics, in phenomena involving radiation, and in cosmology. In all these cases, what is puzzling is why the physical world should be asymmetric in time at all, given that the underlying physical laws seem to be very largely symmetric. These chapters look at some of the attempts that physicists have made to solve this puzzle, and draw attention to some characteristic confusions and fallacies that these attempts tend to involve.

Chapter 2 deals with thermodynamics. Few ideas in modern physics have had as much impact on popular imagination and culture as the second law of thermodynamics. As everyone knows, this is a time-asymmetric principle. It says that entropy *increases* over time. In the late nineteenth century, as thermodynamics came to be addressed in terms of the symmetric framework of statistical mechanics, the puzzle just described came slowly into view: where does the asymmetry of the second law come from? I shall explain how, as this problem came into view, it produced the first examples of a kind of fallacy which has often characterized attempts to explain temporal asymmetry in physics. This fallacy involves a kind of special pleading, or double standard. It takes an argument which could be used equally well in either temporal direction and applies it selectively, in one direction but not the other. Not surprisingly, this biased procedure leads to asymmetric conclusions. Without a justification for the bias, however, these conclusions tell us nothing about the origins of the real asymmetry we find in the world.

Fallacies of this kind crop up time and time again. One of the main themes of this book is that we need the right starting point in order to avoid them. In chapter 2 I'll use examples from the history of thermodynamics to illustrate this idea. I shall also describe an exceptional early example of the required atemporal viewpoint, in the work of Ludwig Boltzmann, the Austrian physicist who was responsible for some of the fundamental results of the period. As we'll see, Boltzmann was perhaps the first person to appreciate the true importance of the question: Why was entropy low in the past? The chapter concludes with a discussion as to what it is that really needs to be explained about the asymmetry of thermodynamics—I shall argue that very few writers have drawn the right lesson from the nineteenth century debate—and offers some guidelines for avoiding the kinds of mistakes that have plagued this field for 150 years.

Chapter 3 looks at the time asymmetry of a wide range of physical phenomena involving radiation. Why do ripples on a water surface spread outwards rather than inwards, for example? Similar things happen with other kinds of radiation, such as light, and physicists have been puzzled by the temporal asymmetry of these phenomena since the early years of the twentieth century. In discussing this issue, it turns out to be important to correct some confusions about what this asymmetry actually involves. However, the chapter's main focus will be the issue of the relation between this asymmetry and that of thermodynamics. I want to show that several prominent attempts to reduce the former asymmetry to the latter turn out to be fallacious, once the nature of the thermodynamic asymmetry is properly appreciated. In particular, I want to look at a famous proposal by the American physicists John Wheeler and Richard Feynman, called the Absorber Theory of Radiation. At first sight, this theory seems to involve the very model of respect for an atemporal perspective. I shall show that Wheeler and Feynman's reasoning is confused, however, and that as it stands, their theory doesn't succeed in explaining the asymmetry of radiation in terms of that of thermodynamics. However, the mathematical core of the theory can be reinterpreted so that it does show—as Wheeler and Feynman believed, but in a different way—that radiation is not intrinsically asymmetric; and that its apparent asymmetry may be traced, if not to the thermodynamic asymmetry itself, then to essentially the same source. (In effect, then, I want to show that Wheeler and Feynman produced the right theory, but tried to use it in the wrong way.)

Chapter 4 turns to cosmology. As chapter 2 makes clear, the search for an explanation of temporal asymmetry leads to the question why the universe was in a very special condition early in its history—why entropy is low near the big bang. But in trying to explain why the universe is like this, contemporary cosmologists often fall for the same kind of fallacies of special pleading, the same application of a double standard with respect to the past and the future, as their colleagues elsewhere in physics. In failing to adopt a sufficiently atemporal viewpoint, then, cosmologists have failed to appreciate how difficult it is to show that the universe must be in the required condition at the big bang, without also showing that it must be in the same condition at the big crunch (so that the ordinary temporal asymmetries would be reversed as the universe recollapsed). Cosmologists who do consider the latter possibility often reject it on grounds which, if applied consistently, would also rule out a low-entropy big bang. As we shall see, the mistakes made here are very much like those made a century earlier, in the attempt to put the asymmetry of thermodynamics on firm statistical foundations. My concern in this chapter is to draw attention to these mistakes, to lay down some guidelines for avoiding them, and to assess the current prospects for a cosmological explanation of temporal asymmetry.

In the first part of the book, then, the basic project is to try to clarify what modern physics tells us about the ways in which the world turns out to be asymmetric in time, what it tells us about how and why the future is different from the past. And the basic strategy is to look at the problem from a sufficiently detached standpoint, so that we don't get misled by the temporal asymmetries of our own natures and ways of thinking. In this way, I argue, it is possible to avoid some of the mistakes which have been common in this branch of physics for more than a century.

In the second part of the book, I turn from the physics of time asymmetry to physics more generally. The big project of this part of the book is to show that the atemporal Archimedean perspective has important ramifications for the most puzzling puzzle of all in contemporary physics: the meaning of quantum theory. My view is that the most promising understanding of quantum theory has been almost entirely overlooked, because physicists and philosophers have not noticed the way in which our ordinary view of the world is a product of our asymmetric standpoint. Once we do notice it—and once we think about what kind of world we might expect, given what we have discovered about the physical origins of time asymmetry—we find that we have good reason to expect the very kind of phenomena which make quantum theory so puzzling. Quantum theory turns out to be the kind of microphysics we might have expected, in other words, given our present understanding of the physical origins of time asymmetry. Most important of all, this path to quantum theory removes the main obstacles to a much more classical view of quantum mechanics than is usually thought to be possible. It seems to solve the problem of nonlocality, for example, and to open the door to the kind of interpretation of quantum theory that Einstein always favored: a view in which there is still an objective world out there, and no mysterious role for observers.

This is a very dramatic claim, and readers are right to be skeptical. If there were a solution of this kind in quantum theory, after all, how could it have gone unnoticed for so long? The answer, I think, is this: the presuppositions this suggestion challenges are so deeply embedded in our ordinary ways of thinking that normally we simply don't notice them. If we do notice them, they seem so secure that the thought of giving them up seems crazy, even in comparison to the bizarre alternatives offered by quantum theory. Only by approaching these presuppositions from an angle which has nothing to do with quantum theory—in particular, by thinking about how they square with what we have discovered about the physical origins of time asymmetry—do we find that there are independent reasons to give them up. Suddenly, this way of thinking about quantum theory looks not just sane, but a natural consequence of other considerations.

What are these presuppositions? They involve notions such as causation and physical dependence. As we ordinarily use them, these notions are strongly time-asymmetric. For example, we take it for granted that events depend on earlier events in a way in which they do not depend on later events. Physicists often dismiss this asymmetry as subjective, terminological, or merely "metaphysical." As we shall see, however, it continues to exert a very powerful influence on their intuition—on what kind of models of the world they regard as intuitively acceptable. It is the main reason why the approach to quantum theory I want to recommend has received almost no serious attention.

In chapters 5–7 I mount a two-pronged attack on this intuition. Chapter 5 shows that it sits very uneasily with the kind of picture of the nature and origins of time asymmetry in physics which emerges from the earlier chapters. In this chapter I also explain in an introductory way why abandoning this intuition would have important and very attractive ramifications in the debate about quantum theory. However, the notions of causation, dependence, and the like are not straightforward. They are notions which have often puzzled philosophers, and their temporal asymmetry is especially mysterious. Is it some extra ingredient of the world, over and above the various asymmetries in physics, for example? Or can it be reduced to those asymmetries? These are philosophical issues, and the second arm of my attack on the intuition mentioned above involves an investigation of its origins, along philosophical lines.

In chapter 6 I argue that the asymmetry of causation cannot be reduced to any of the available physical asymmetries, such as the second law of thermodynamics. The basic problem for such a reduction is that the available physical asymmetries are essentially macroscopic, and therefore cannot account for causal asymmetry in microphysics—though our causal intuitions are no less robust when applied to this domain than they are elsewhere. I argue instead that the asymmetry of causation is anthropocentric in origin. Roughly, it reflects the time-asymmetric perspective we occupy as *agents* in the world—the fact that we deliberate for the *future* on the basis of information about the *past,* for example.

As I explain in chapter 7, this account has the satisfying consequence that despite its powerful grip on our intuitions—a grip which ought to seem rather puzzling, in view of the apparent symmetry of physics itself—causal asymmetry does not reflect a further ingredient of the world, over and above what is already described by physics. It doesn't multiply the objective temporal "arrows," in other words. More surprisingly, we shall see that the account does leave room for a limited violation of the usual causal order. In other words, it leaves open the possibility that the world might be such that from our standard asymmetric perspective, it would be appropriate to say that certain of our present actions could be the causes of *earlier* effects. In failing to recognize this possibility, physics has failed to practice what it has often preached concerning the status of causal asymmetry. Having often concluded, rightly, that the asymmetry of causation is not a physical matter, physicists have then failed to notice that the anthropocentric framework continues to constrain their construction of models of reality. One of the great attractions of the Archimedean standpoint is that it serves to break these conventional bonds, and hence to free physics from such self-imposed constraints.

The last two chapters apply these lessons to the puzzles of quantum mechanics. Chapter 8 provides an informal overview of the long debate about how quantum mechanics should be interpreted, identifying the main positions and their advantages and disadvantages. As I'll explain, the best focus for such an overview is the question that Einstein took to be the crucial one about quantum mechanics: Does it give us a complete description of the systems to which it applies?

Famously, Einstein thought that quantum theory is incomplete, and that there must be some further, more classical reality "in the background." His great disagreement with Niels Bohr centered on this issue. Einstein is often said to have lost the argument, at least in hindsight. (The work of John Bell in the 1960s is often thought to have put the final nail in Bohr's case, so to speak.) I think this verdict is mistaken. Despite Bell's work, Einstein's view is very much less implausible than it is widely taken to be, at least in comparison to the opposing orthodoxy.

This conclusion is overshadowed by that of chapter 9, however, where I show how dramatically the picture is altered if we admit the kind of backward causation identified in chapter 7. In the quantum mechanical literature this possibility is usually dismissed, or simply overlooked, because it flies in the face of such powerful intuitions about causality. But the lesson of chapter 7 is that when we ask where these intuitions come from, we discover that their foundations give us no reason at all to exclude the kind of limited backward influence in question—on the contrary, if anything, because powerful symmetry principles can be made to work in favor of the proposal.

In effect, then, my conclusion in chapter 9 is that the most promising and well-motivated approach to the peculiar puzzles of quantum mechanics has been almost entirely neglected, in part because the nature and significance of our causal intuitions have not been properly understood. Had these things been understood in advance—and had the real lessons of the nineteenth-century debate about temporal asymmetry been appreciated a century ago—then quantum mechanics is the kind of theory of microphysics that the twentieth century might well have expected.

REMARKS ON STYLE

A few remarks on the style and level of the book. Much of the argument is philosophical in character. It deals with live issues in contemporary physics, however, and takes for granted that it is physicists who need to be convinced of the advantages of the Archimedean standpoint. The book thus faces the usual hurdles of an interdisciplinary work, with the additional handicap of a far-reaching and counterintuitive conclusion. There is a danger that specialist readers on both sides will feel that my treatment of their own material is simplistic or simply wrong, and that my account of the other side's contribution is difficult, obscure and of doubtful relevance. Physicists are more likely to have the first reaction, of course, and philosophers the second, because I am writing from a philosophical standpoint.

There are conflicting constraints here, but the best approach seems to be to try to maximize clarity and readability, even if sometimes at the expense of rigor and precision. I have tried in particular to keep philosophical complexity to a minimum, in order to make the general viewpoint as accessible as possible to readers from other fields. On the physical side I had less choice in the matter—my own technical abilities soon reach their limits—but here too, where possible, I have tried to opt for accessibility rather than precision. Occasionally, where technicality of one sort or the other seemed especially important, I have tried to quarantine it, so that the details may be skipped by readers who are disinclined to tangle. (In these cases I indicate in the text which sections can be skipped.) Most chapters finish with a summary, and there is an overview of the book as a whole at the end.

Finally, a hint for impatient readers, keen to get into the quantum mechanics: start at chapter 5, and follow the arrows from there.

THE STOCK PHILOSOPHICAL DEBATES ABOUT TIME

The philosophy of time has a long history, and is unusual even by philosophical standards for the durability of some of its main concerns. In a modern translation much of Saint Augustine's work on time would pass for twentieth-century philosophy. Augustine's concerns are often exactly those of modern philosophers. He is puzzled about the nature of the distinctions between the past, the present, and the future, and about the fact that the past and the future seem unreal: the past has ceased to exist, and the future doesn't yet exist. And he is concerned about the nature and status of the apparent flow of time.

These two problems—the first the status of the past-present-future distinction, and the related concern about the existence of the past and the future, and the second the issue of the flow of time—remain the focus of much work in the philosophy of time. As I noted earlier, philosophers tend to divide into two camps. On one side there are those who regard the passage of time as an objective feature of reality, and interpret the present moment as the marker or leading edge of this advance. Some members of this camp give the present ontological priority, as well, sharing Augustine's view that the past and the future are unreal. Others take the view that the past is real in a way that the future is not, so that the present consists in something like the coming into being of determinate reality.

Philosophers in the opposing camp regard the present as a subjective notion, often claiming that *now* is dependent on one's viewpoint in much the same way that *here* is. Just as "here" means roughly "this place," so "now" means roughly "this time," and in either case what is picked out depends where the speaker stands. On this view there is no more an objective division of the world into the past, the present, and the future than there is an objective division of a region of space into here and there. Not surprisingly, then, supporters of this view deny that there is any ontological difference—any difference concerning simply *existence*—between the past, the present, and the future.

Often this is called the *block universe view,* the point being that it regards reality as a single entity of which time is an ingredient, rather than as a changeable entity set *in* time. The block metaphor sometimes leads to confusion, however. In an attempt to highlight the contrast with the dynamic character of the "moving present" view of time, people sometimes say that the block universe is *static*. This is rather misleading, however, as it suggests that there is a time frame in which the four-dimensional block universe stays the same. There isn't, of course. Time is supposed to be included in the block, so it is just as wrong to call it static as it is to call it dynamic or changeable. It isn't any of these things, because it isn't the right sort of entity—it isn't an entity *in* time, in other words.

Defenders of the block universe view deny that there is an objective present, and usually also deny that there is any objective flow of time. Indeed, perhaps the strongest reason for denying the objectivity of the present is that it is so difficult to make sense of the notion of an objective flow or passage of time. Why? Well, the stock objection is that if it made sense to say that time flows then it would make sense to ask how fast it flows, which doesn't seem to be a sensible question. Some people reply that time flows at one second per second, but even if we could live with the lack of other possibilities, this answer misses the more basic aspect of the objection. A rate of seconds per second is not a rate at all in physical terms. It is a dimensionless quantity, rather than a rate of any sort. (We might just as well say that the ratio of the circumference of a circle to its diameter flows at π seconds per second!)

A rarer but even more forceful objection is the following. If time flowed, then—as with any flow—it would only make sense to assign that flow a *direction* with respect to a choice as to what is to count as the positive direction of time. In saying that the sun moves from east to west or that the hands of a clock move clockwise, we take for granted the usual convention that the positive time axis lies toward what we call the future. But in the absence of some objective grounding for this convention, there isn't an objective fact as to which way the sun or the hands of the clock are "really" moving. Of course, proponents of the view that there is an objective flow of time might see it as an advantage of their view that it does provide an objective basis for the usual choice of temporal coordinate. The problem is that until we have such an objective basis we don't have an objective sense in which time is flowing one way rather than the other. In other words, not only does it not seem to make sense to speak of an objective *rate* of flow of time; it also doesn't make sense to speak of an objective *direction* of flow of time.

These problems in making sense of an objective flow of time spill over on the attempt to make sense of an objective present. For example, if the present is said to be the "edge" at which reality becomes concrete, at which the indeterminacy of the future gives way to the determinacy of the past, then the argument just given suggests that there isn't an objective sense in which reality is growing rather than shrinking.

These objections are all of a philosophical character, not especially dependent on physics. A new objection to the view that there is an objective present arises from Einstein's theory of special relativity. The objection is most forceful if we follow Augustine in accepting that only the present moment is real. For then if we want to inquire what reality includes, apart from our immediate surroundings, we need to think about what is *now* happening elsewhere. However, Einstein's theory tells us that there is no such thing as objective simultaneity between spatially separated events. Apparent simultaneity differs from observer to observer, depending on their state of motion, and there is no such thing as an objectively right answer. So the combination of Augustine and Einstein seems to give us the view that reality too is a perspective-dependent matter. The distinctive feature of the Augustinian view—the claim that the content of the present moment is an objective feature of the world—seems to have been lost.

Augustine's own reasons for believing in the objectivity of the present—indeed, the nonreality of everything else—seem to have been at least partly linguistic. That is, he was moved by the fact that we say such things as "There are no dinosaurs—they no longer exist" and "There is no cure for the common cold—it doesn't yet exist." By extrapolation, it seems equally appropriate to say that there is no past, for it no longer exists; and that there is no future, for it does not yet exist. However, a defender of the block universe view will say that in according these intuitions the significance he gives them, Augustine is misled by the tense structure of ordinary language. In effect, he fails to notice that "Dinosaurs do not exist" means "Dinosaurs do not exist *now*." As a result, he fails to see that the basic notion of existence or reality is not the one that dinosaurs are here being said to lack—viz., existence *now*—but what we might term existence *somewhen*. Again the spatial analogy seems helpful: we can talk about existence in a spatially localized way, saying, for example, that icebergs don't exist here in Sydney; but in this case it is clear that the basic notion of existence is the unqualified one—the one that we would describe as existence *somewhere*, if language required us to put in a spatial qualification. We are misled in the temporal case because the simplest grammatical form actually includes a temporal qualification.

So it is doubtful whether Augustine's view can be defended on linguistic grounds. In practice, the most influential argument in favor of the objective present and objective flow of time rests on an appeal to psychology—to our own experience of time. It seems to us as if time flows, the argument runs, and surely the most reasonable explanation of this is that there is some genuine movement of time which we experience, or in which we partake.

Arguments of this kind need to be treated with caution, however. After all, how would things seem if it time didn't flow? If we suppose for the moment that there is an objective flow of time, we seem to be able to imagine a world which would be just like ours, except that it would be a four-dimensional block universe rather then a three-dimensional dynamic one. It is easy to see how to map events-at-times in the dynamic universe onto events-at-temporal-locations in the block universe. Among other things, our individual mental states get mapped over, moment by moment. But then surely our copies in the block universe would have the same experiences that we do—in which case they are not distinctive of a dynamic universe after all. Things would seem this way, even if we ourselves were elements of a block universe.

Proponents of the block universe view thus argue that in the case of the apparent flow of time, like that of the apparent objectivity of the present, it is important to draw a distinction between how things *seem* and how they actually are. Roughly speaking, what we need to do is to explain why things *seem* this way, without assuming that the "seeming" corresponds directly to anything in reality. Explanations of this kind are quite common in philosophy. Their general strategy is to try to identify some characteristic of the standpoint from which we "see" the appearance in question, such that the nature of the appearance can be explained in terms of this characteristic of the viewpoint. (There are lots of commonplace examples of this kind of thing. Rose-tinted spectacles explain why the world seems warm and friendly to those who wear them.)[4]

One of my projects in this book is to try to extend these insights about the consequences of the temporal perspective from which we view the world. We are interested in this partly for its bearing on the attempt to explain the arrow of time—existing attempts often go wrong because they fail to notice the influence of this perspective on ordinary ways of thinking—but also for its general philosophical interest. In this respect, as I said earlier, the book is an attempt to further the project of philosophical writers such as Williams, Smart, and Mellor.

From now on I shall simply take for granted the main tenets of the block universe view. In particular, I'll assume that the present has no special objective status, instead being perspectival in the way that the notion of *here* is. And I'll take it for granted that there is no objective flow of time. These assumptions will operate mainly in a negative way. I shall not explore the suggestion that flow gives direction to time, for example, because I shall be taking for granted that there is no such thing as flow.

In making these assumptions I don't mean to imply that I take the arguments for the block universe view sketched above to be conclusive. I do think that it is a very powerful case, by philosophical standards. However, the aim of the book is to explore the consequences of the block universe view in physics and philosophy, not to conduct its definitive defense. My impression is that these consequences give us new reasons to favor the view over its Augustinian rival, but others might take the point in reverse, finding here new grounds for the claim that the block universe leaves out something essential about time. Either way, all that matters to begin with is that the block universe view is not already so implausible that it would a waste of time to seek to extend it in this way, and this at least is not in doubt.

THE ARROWS OF TIME

Our main concern is with the asymmetry of time, but what does this mean? The terminology suggests that the issue concerns the asymmetry *of time itself,* but this turns out not to be so. To start with, then, we need to distinguish the issue of the asymmetry *of* time from that of the asymmetry of things *in* time. The easiest way to do this is to use a simple spatial analogy.

Imagine a long narrow table, set for a meal. The contents of the table might vary from end to end. There might be nonvegetarian food at one end and vegetarian at the other, for example; there might be steak knives at one end but not at the other; all the forks might be arranged so as to point to the same end of the table; and so on. This would constitute asymmetry *on* the table. Alternatively, or as well, the table itself might vary from end to end. It might be wider or thicker at one end than the other, for example, or even bounded in one direction but infinite in the other. (This might be a meal on Judgment Day, for example, with limited seating at the nonvegetarian end.) These things would be asymmetries *of* the table—asymmetries of the table itself, rather than its contents.

There seems to be an analogous distinction in the case of time. Time itself might be asymmetric in various ways. Most obviously, it might be bounded in one direction but not in the other. There might be an earliest time but no latest time. There are other possibilities: as long as we think of time as a kind of extended "stuff," there will be various ways in which the characteristics of this stuff might vary from end to end. More contentiously, if sense could be made of the notion of the flow of time, then that too might provide a sense in which time itself had an intrinsic direction or asymmetry. (However, supporters of the objective present/objective flow view are likely to be unhappy with this use of a spatial metaphor to characterize the distinction between the asymmetry of time and that of things in time.)

Independently of the issue as to whether time itself is symmetric from end to end, there is an issue about whether the physical contents of time are symmetric along its axis. This is analogous to the question as to whether the contents of the table are symmetric from end to end. It turns out that the interesting questions about temporal asymmetry are very largely of this kind.

There are various respects in which the contents of the block universe appear to be arranged asymmetrically with respect to the temporal axis. For example, many common physical processes seem to exhibit a very marked temporal preference, occurring in one temporal orientation but not the other. This is why the events depicted in reversed films often seem bizarre. In the real world, buildings may collapse into rubble, for example, but rubble does not "uncollapse" to form a building—even though, as it happens, the latter process is no less consistent than the former with the laws of mechanics. (It is this last fact that makes the asymmetry so puzzling—more on this in a moment.)

As we shall see in the following chapters, there are a number of apparently distinct ways in which the world we inhabit seems asymmetric in time. One of the tasks of an account of temporal asymmetry is thus a kind of taxonomic one: that of cataloging the different asymmetries (or "arrows," as they have come to be called), and sorting out their family relationships. Physicists in particular have been interested in the question as to whether there is a single "master arrow," from which all the others are in some sense derived. As we shall see, the leading candidate for this position has been the so-called arrow of thermodynamics. This is the asymmetry embodied in the second law of thermodynamics, which says roughly that the entropy of an isolated physical system never decreases.

As a gentle introduction to the kind of reasoning on which much of the book depends, note that this formulation of the second law assumes a choice of temporal orientation. It assumes that we are taking the "positive" temporal direction to be that of what we ordinarily call the future. There is nothing to stop us taking the positive axis to lie in the opposite direction, however, in which case the second law would need to be stated as the principle that the entropy of an isolated system never *increases.* The lesson is that the objective asymmetry consists in the presence of a unidirectional gradient in the entropy curve of, apparently, all isolated physical systems. Each such system exhibits such a gradient, and all the gradients slope in the same temporal direction. But it is not an objective matter whether the gradients *really* go up or go down, for this simply depends on an arbitrary choice of temporal orientation. They don't *really* go either way, from an atemporal viewpoint.

THE PUZZLE OF ORIGINS

One of the problems of temporal asymmetry is thus to characterize the various temporal arrows—asymmetries of things *in* time—and to explain how they relate to one another. Let's call this the *taxonomy problem.* The second problem—call it the *genealogy problem*—is to explain why there is *any* significant asymmetry of things in time, given that the fundamental laws of physics appear to be (almost) symmetric with respect to time. Roughly, this symmetry amounts to the principle that if a given physical process is permitted by physical laws, so too is the reverse process—what we would see if a film of the original process were shown in reverse. With one tiny exception—more on this in a moment—modern physical theories appear to respect this principle. This means that insofar as our taxonomy of temporal arrows reveals significant asymmetries—significant cases in which the world shows a preference for one temporal orientation of a physical process over the other, for example—it is puzzling how these asymmetries could be explained in terms of the available physical theories. How are we going to explain why buildings collapse into rubble but rubble does not "uncollapse" into buildings, for example, if both processes are equally consistent with the laws of mechanics? We seem to be trying to pull a square rabbit from a round hat!

As I noted, however, there seems to be one little exception to the principle that the basic laws of physics are time-symmetric. This exception, first discovered in 1964, concerns the behavior of a particle called the neutral kaon. To a very tiny extent, the behavior of the neutral kaon appears to distinguish past and future—an effect which remains deeply mysterious.[5] Tiny though it is, could this effect perhaps have something to do with the familiar large-scale asymmetries (such as the tendency of buildings to collapse but not "uncollapse")? At present, it is difficult to offer a convincing answer to this question, one way or the other. The best strategy is to set the case of the kaon to one side, and to study the more familiar arrows of time in physics as if there were no exceptions to the principle that the underlying laws are time-symmetric. This way we can find out where the puzzles really lie—and where, if at all, the kaon might have a role to play.[6]

Physicists and philosophers have long been puzzled by the genealogy problem. The most famous attempt to provide at least a partial solution dates from the second half of the nineteenth century, when Boltzmann claimed to have derived the second law of thermodynamics for the case of gases from a statistical treatment within the symmetrical framework of Newtonian mechanics. As we shall see in the next chapter, however, Boltzmann's critics soon pointed out that he had relied on a temporally asymmetric assumption (the so-called *stoßzahlansatz,* or "assumption of molecular chaos"). Boltzmann's argument thus provides an early example of what has proved a common and beguiling fallacy. In search of an explanation for the observed temporal asymmetries—for the observed difference between the past and the future, in effect—people unwittingly apply different standards with respect to the two temporal directions. The result is that the asymmetry they get out is just the asymmetry they put in. Far from being solved, the problems of temporal asymmetry are obscured and deferred—the lump in the carpet is simply shifted from one place to another. In the course of the book we shall encounter several examples of this kind of mistake.

The reason the mistake is so prevalent is not (of course) that the physicists and philosophers who have thought about these problems are victims of some peculiar intellectual deficit. It is simply that temporal asymmetry is so deeply ingrained in our ways of thinking about the world that it is very difficult indeed to spot these asymmetric presuppositions. Yet this is what we need to do, if we are to disentangle the various threads in the problem of temporal asymmetry, and in particular to distinguish those threads that genuinely lie in the world from those that merely reflect our own viewpoint. In order to explain temporal asymmetry it is necessary to shake off its constraints on our ordinary ways of thinking—to stand in thought at a point outside of time, and thence to regard the world in atemporal terms. This book is a kind of self-help manual for those who would make this Archimedean journey.

To put the project in perspective, let us reflect again on the history of science, or natural philosophy more generally. In hindsight it is easy to see that our view of the world has often unwittingly embodied the peculiarities of our own standpoint. As I noted earlier, some of the most dramatic episodes in the history of science are associated with the unmasking of distortions of this kind. I mentioned Copernicus and Darwin. Another striking example is the conceptual advance that led to Newton's first law of motion. This advance was Galileo's appreciation that the friction-dominated world of ordinary mechanical experience was not the natural and universal condition it had been taken to be. Left to its own devices, a moving body would move forever.

In the same historical period we find a parallel concern with the philosophical aspects of the project of uncovering the anthropocentricities of our ordinary view of the world. We find an interest in what soon came to be called the distinction between primary and secondary qualities, and an appreciation that the proper concern of physics is with the former: that is, with those aspects of the world that are not the product of our own perceptual peculiarities.

Consider these remarks from Galileo himself, for example, in 1623:

> I feel myself impelled by the necessity, as soon as I conceive a piece of matter or corporeal substance, of conceiving that in its own nature it is bounded and figured in such and such a figure, that in relation to others it is large or small, that it is in this or that place, in this or that time, that it is in motion or remains at rest, that it touches or does not touch another body, that it is single, few, or many; in short by no imagination can a body be separated from

> such conditions; but that it must be white or red, bitter or sweet, sounding or mute, of a pleasant or unpleasant odour, I do not perceive my mind forced to acknowledge it necessarily accompanied by such conditions; so if the senses were not the escorts, perhaps the reason or the imagination by itself would never have arrived at them. Hence I think that these tastes, odours, colours, etc., on the side of the object in which they seem to exist, are nothing else than mere names, but hold their residence solely in the sensitive body; so that if the animal were removed, every such quality would be abolished and annihilated.[7]

Galileo is telling us that tastes, odors, colors, and the like are not part of the objective furniture of the world; normally, in thinking otherwise, we mistake a by-product of our viewpoint for an intrinsic feature of reality. In Galileo and later seventeenth-century writers, the move to identify and quarantine these secondary qualities is driven in part by the demands of physics; by the picture supplied by physics of what is objective in the world. This is not a fixed constraint, however. It changes as physics changes, and some of these changes themselves involve the recognition that some ingredient of the previously excepted physical world view is anthropocentric.

These examples suggest that anthropocentrism infects science by at least two different routes. In some cases the significant factor is that we happen to live in an exceptional part of the universe. We thus take as normal what is really a regional specialty: geocentric gravitational force, or friction, for example. In other cases the source is not so much in our *location* as in our *constitution.* We unwittingly project onto the world some of the idiosyncrasies of our own makeup, seeing the world in the colors of the in-built glass through which we view it. But the distinction between these sources is not always a sharp one, because our constitution is adapted to the peculiarities of our region.

It is natural to wonder whether modern physics is free of such distortions. Physicists would be happy to acknowledge that physics might uncover new locational cases. Large as it is, the known universe might turn out to be an unusual bit of something bigger.[8] The possibility of continuing constitutional distortions is rather harder to swallow, however. After all, it challenges the image physics holds of itself as an objective enterprise, an enterprise concerned with not with how things *seem* but with how they actually *are.* It is always painful for an academic enterprise to have to acknowledge that it might not have been living up to its own professed standards!

In the course of the book, however, I want to argue that in its treatment of time asymmetry, contemporary physics has failed to take account of distortions of just this constitutional sort—distortions which originate in the kind of entities we humans are, in one of our most fundamental aspects. If we see the historical process of detection and elimination of anthropocentrism as one of the adoption of progressively more detached standpoints for science, my claim is that physics has yet to achieve the standpoint required for an understanding of temporal asymmetry. In this case the required standpoint is an atemporal one, a point outside time, a point free of the distortions which stem from the fact that we are creatures in time—truly, then, a view from nowhen.

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Overview

At the beginning of the book I described two opposing viewpoints in the philosophy of time. One view holds that the present moment and the flow of time are objective features of reality. The other view disagrees, treating the apparent objectivity of both these things as a kind of artifact of the particular perspective that we humans have on time. According to the latter view what is objective is the four-dimensional "block universe," of which time is simply a part. In chapter 1, I outlined some of the attractions of the block universe view. Since then, the project of the book has been to explore its consequences in physics, in two main respects: first, in connection with the attempt to understand various puzzling temporal asymmetries in physics; and second, by way of its bearing on various time-asymmetric presuppositions, which turn out to play a crucial role in standard ways of thinking about quantum mechanics.

In particular, I have been trying to correct a variety of common mistakes and misconceptions about time in contemporary physics—mistakes and misconceptions whose origins lie in the distorting influence of our own ordinary temporal perspective, and especially of the time asymmetry of that perspective. One important aspect of this problem is a matter of sorting out how much of the temporal asymmetry we think we see in the world is objective, and how much is simply a by-product of our own asymmetry. I have urged that in order to clarify these issues, and to avoid these mistakes, we need to learn to set aside some very deeply ingrained habits of thought. We need to familiarize ourselves with an atemporal perspective—an Archimedean "view from nowhen."

The physical and philosophical concerns of the book have thus been very closely intertwined. The book's conclusions have emerged at a variety of levels, in a variety of voices. Some were substantial proposals concerning contemporary problems in physics or philosophy, others were prescriptions for the proper conduct of these disciplines from the Archimedean standpoint, and so on. In order to help readers to put the whole thing in perspective, I have listed below, by chapter, the main conclusions of the book.

In this book, especially, it would be out of character if the overview looked only in one direction. I finish, therefore, with a few pointers to future work—to the kinds of issues that look important in physics and philosophy, in light of these conclusions.

MAIN CONCLUSIONS OF THE BOOK

CHAPTER 2. *The Lessons of the Second Law*

• What needs to be explained is the low-entropy past, not the high entropy future—why entropy goes down toward the past, not why it goes up toward the future.

• To a significant extent, then, the H-theorem and its descendants address a pseudo-problem.

• The traditional criticism of the H-theorem—viz., that it assumes temporal asymmetry in disguised form—turns out to be well motivated but misdirected. The important issue is not whether we are entitled to assume the *stoßzahlansatz* (or PI^3, the Principle of the Independence of Incoming Influences) toward the future, but why these independence principles do not hold toward the past.

• We need to guard against the double standard fallacy—that of accepting arguments with respect to one temporal direction which we wouldn't accept with respect to the other.

• The most useful technique for avoiding these fallacies involves imagined time reversal. If an apparently acceptable argument looks counterintuitive when we imagine time reversed, it is a good indication that a double standard is in play. In effect, this simple technique provides temporal creatures such as ourselves with a reliable and readily accessible guide to the standards that would apply from a genuinely atemporal perspective.

CHAPTER 3. *New Light on the Arrow of Radiation*

• The issue concerning the asymmetry of radiation is sometimes misrepresented. Correctly understood, it is that as to why there are large coherent sources in the past but not (apparently) in the future.

• A proper understanding of the problem of temporal asymmetry in thermodynamics shows that a common argument which claims to derive this asymmetry of radiation from the thermodynamic behavior of matter (e.g., the edges of ponds) is fallacious, for it needs to assume the absence of the very boundary conditions—viz., coherent sources of advanced radiation—that it seeks to exclude.

• This fallacy is even more serious in the Wheeler-Feynman Absorber Theory, which explicitly assumes that there really is advanced radiation, although we don't see it.

• The issue of the asymmetry of radiation thus turns out to be parallel to (rather than *reducible to*) that raised by thermodynamics, in the sense that it too directs us to the existence of highly ordered conditions in the past.

• This diagnosis of the nature of the asymmetry of radiation is confirmed by our reinterpreted version of the Wheeler-Feynman theory, which shows that radiation can be considered to be symmetric at the micro level.

• The argument for the proposed reinterpretation reveals other flaws in the standard version of the Wheeler-Feynman theory.

CHAPTER 4. *Arrows and Errors in Contemporary Cosmology*

• The asymmetries of thermodynamics and radiation appear to depend on the fact that the universe had a particular character early in its history: its matter was very evenly distributed, which is a very ordered condition for a system in which gravity is the dominant force.

• Contemporary cosmologists continue to underestimate the difficulty of explaining this condition of the early universe without showing that the universe must be in the same condition at its other temporal extremity (which would imply that the familiar asymmetries would reverse as the universe recollapsed). Blindness to this difficulty—the *basic dilemma,* as I called it—stems from double standard fallacies.

• Many arguments against the symmetric collapse model also involve double standard fallacies, particularly in relying on statistical reasoning which would equally exclude a low-entropy big bang.

• There are important questions concerning the consistency and observability of a time-reversing collapse which—because it has been rejected on spurious grounds—have not been properly addressed by physics.

• Although in many ways further advanced than it was in the late nineteenth century, the contemporary discussion of temporal asymmetry in physics is still plagued by some of the same kinds of mistakes.

CHAPTER 5. *Innocence and Symmetry in Microphysics*

• It is important to distinguish two forms of PI^3: the macroscopic case, associated with the fact that the universe has a low-entropy past, and a microscopic case, almost universally taken for granted in physics. The microscopic case embodies the intuitively plausible principle of μInnocence: interacting systems are uncorrelated before they first interact.

• Unlike its macroscopic cousin, the acceptance of μInnocence does not rest on observational grounds. As it currently operates in physics, it is an independent asymmetric principle, in conflict with the assumed T-symmetry of (almost all) the underlying laws of microphysics.

• Hence there is a deep and almost unrecognized conflict in contemporary physics. If we are to retain T-symmetry, we should abandon μInnocence.

• Quantum mechanics suggests that there might be good independent reasons for abandoning μInnocence. μInnocence turns out to be a presupposition of the main arguments for thinking that there is something especially puzzling about quantum mechanics. In other words, quantum mechanics seems to offer empirical confirmation that μInnocence fails.

• The failure of μInnocence seems to open the way for a kind of backward causation. However, well-recognized features of quantum mechanics seem to block the paradoxes to which backward causation is often thought to lead. But the suggestion raises wider issues about the asymmetry of causation itself, which need to be addressed in their own terms, before the proposal concerning μInnocence can be evaluated properly.

Chapter 6. *In Search of the Third Arrow*

• Although the asymmetry of causation is often said by physicists to be of no relevance to contemporary physics, it continues to exert a great influence on the practice of physics. Hence its interest is not merely philosophical: it needs to be understood, so that this influence may be assessed.

• The most popular philosophical approach to the asymmetry of causation is the third arrow strategy, which seeks to analyze causal asymmetry in terms of a de facto physical asymmetry. However, it turns out that the available candidates are not appropriately distributed in the world. In particular, they fail at the micro level.

• This point is often obscured by fallacies similar to those which plague attempts to account for the physical temporal asymmetries: double standards and buck-passing, for example.

• The most plausible solution is the anthropocentric one: the asymmetry of causation is a projection of our own temporal asymmetry as agents in the world.

Chapter 7. *Convention Objectified and the Past Unlocked*

• The diagnosis of the previous chapter finds attractive expression in terms of the conventional asymmetry of counterfactual conditionals. However, the conventionalist view seems to make the asymmetry of dependence—the fact that the future depends on the past, but not vice versa—insufficiently objective, in two senses: it seems too weak, in making the asymmetry conventional, and too strong, in ruling out backward causation by fiat.

• The conventionalist view meets the first point by noting that the convention is not a matter of choice, and thereby explaining its apparent objectivity.

• The conventionalist view meets the second point by showing that there is a loophole which allows backward dependence, in circumstances in which an agent's access to past events is limited in certain ways.

• The admission of backward dependence requires an appropriate disambiguation of the relevant convention governing our use of counterfactuals. The disambiguation in question is a matter of linguistic choice, but it is an objective matter whether the world is such as to require us to make this choice.

• Hence there is an objective possibility concerning the way in which the microworld is structured, which has been all but obscured by our familiar intuitions concerning causation, μInnocence, and the like. As in chapter 5, moreover, it turns out that there is a strong symmetry argument in favor of the hypothesis that the microworld actually has a structure of this kind.

• Temporal symmetry alone might thus have led us to expect a kind of backward causation, or *advanced action,* in microphysics.

CHAPTER 8. *The Puzzle of Contemporary Quantum Theory*

This chapter presented a broad overview of the conceptual issues concerning the interpretation of quantum mechanics, emphasizing the central role of the issue as to whether quantum mechanics is complete. In setting out the difficulties faced by the competing approaches to this issue, my exposition mainly followed conventional lines, but made a few distinctive claims:

• I argued that hidden variable approaches are in a stronger position than is usually recognized. Given that all conventional views admit nonlocality, it is not a decisive objection to hidden variable views that they too are required to do so. In terms of the conventional debate—the debate which ignores advanced action—then, the contextualist approach remains underexplored.

• I noted that no collapse views face a difficulty concerning the meaning of probability in quantum mechanics which is even more severe than has previously been recognized, even by philosophical critics.

CHAPTER 9. *The Case for Advanced Action*

• Bell's Theorem depends on the independence assumption, which might be relaxed in two ways: dependence may be secured either in the past, via a common cause, or in the future, via the kind of advanced action whose formal possibility we identified in chapter 7. If successful, either of these strategies would enable quantum mechanics to avoid nonlocality.

• The common cause strategy seems initially the more attractive strategy in light of our ordinary causal intuitions, but calls for an implausible substructure underlying ordinary physical processes.

• The advanced action is elegant and economical is comparison, and has the symmetry advantage noted in chapter 6. Quantum mechanics supplies the restrictions on classical observability that the argument of chapter 6 led us to expect.

• The benefits of the advanced action proposal are not confined to Bell's Theorem; the proposal also undercuts the non-EPR no hidden variable theorems, and the new GHZ argument for nonlocality.

• Quantum mechanics might be interpreted as providing a complete description *from a limited or partial perspective:* a complete view of the world *as accessible from the temporal standpoint we normally occupy.* This is compatible with the claim that it is an incomplete description of what would be seen from the Archimedean standpoint.

• This suggestion raises important issues concerning the extent to which the ordinary conceptual framework of physics depends on the temporal viewpoint, for example, in its use of concepts such as *degree of freedom* and *potential,* and methods such as statistical reasoning. In this respect the proper form of an atemporal "physics from nowhen" is a issue left open by this book.

DIRECTIONS FOR FURTHER WORK

What sorts of projects look important in the light of these conclusions? There is work for both physicists and philosophers, I think.

In physics

• Exploration of models incorporating advanced action, especially in quantum mechanics.

• Exploration of the consistency and possible empirical consequences of symmetric time-reversing cosmologies, and more generally of the issue of the observability of phenomena constrained by future low-entropy boundary conditions.

• The project of explaining the low-entropy big bang, with the basic dilemma clearly in view.

In philosophy

• The issue of the proper conceptual framework for an atemporal physics. How much of the conceptual machinery of conventional physics depends on our familiar temporal perspective?

• Similar issues in metaphysics more generally. I have argued that causation and physical dependence are importantly anthropocentric notions, whose temporal asymmetry reflects the contingencies of our own temporal stance. But what would a properly atemporal metaphysics be like?

WHY IT MATTERS

In what sense do these issues matter? Why shouldn't we ignore the view from nowhen, and go on in physics, philosophy, and ordinary life just as we always have? After all, we cannot actually step outside time, in the way in which we can climb a tree to alter our viewpoint. Isn't it better to be satisfied with the viewpoint we have?

We cannot step outside time, but we can try to understand how the way in which we are situated within time comes to be reflected in the ways in which we talk and think and conceptualize the world around us. What we stand to gain is a deeper understanding of ourselves, and hence—by subtraction, as it were—a deeper understanding of what is external to us. This is a reflective kind of knowledge: we reflect on the nature of the standpoint from within, and thereby gain some sense—albeit, ultimately, a sense-from-within—of what it would be like from without.

If the reflexivity were vicious the project would be self-defeating, but is it vicious? Our understanding seems to be enhanced, not overturned. The issue here is an old one: science has long stood proxy in this way for creatures—ourselves—whose own epistemological connections with the world are tenuous, patchy, contingent, and parochial. With each advance comes a new picture of how the world would look from nowhere, and a new appreciation of the limits of our own standpoint. At each stage there is a temptation to think that our standpoint is devalued, but this seems to be a mistake. If we had a choice of standpoints we might choose a different one, but to be swayed by this would be like wanting to be someone else.[1] Because our standpoint is not a matter of choice—no more so than it is a matter of choice who we are—it cannot coherently be undermined in this way.

The campaign for a view from nowhen is a campaign for self-improvement, then, and not a misguided attempt to do the impossible, to become something that we can never be. It promises only to enhance *our* understanding of ourselves and our world, and not to make us gods.