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Studies in Epistemology, Logic, Methodology,
and Philosophy of Science

Nicholas Maxwell

The Metaphysics of Science and Aim-Oriented Empiricism

A Revolution for Science and Philosophy



Springer

Synthese Library

Studies in Epistemology, Logic, Methodology,
and Philosophy of Science

Volume 403

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A Revolution for Science and Philosophy

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Synthese Library

ISBN 978-3-030-04142-7

ISBN 978-3-030-04143-4 (eBook)

<https://doi.org/10.1007/978-3-030-04143-4>

Library of Congress Control Number: 2018962007

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Preface

This book is about work that I have done on the metaphysics of science and its reception – or rather, lack of reception. It came in two waves.

The first wave was devoted to the mind-body problem – or to the broader and more general human world/physical universe problem: How can our human world exist and best flourish embedded as it is in the physical universe? My research was devoted to this problem from about 1964 to 1968. Snippets of this work had an immense impact on subsequent philosophy but, unfortunately for me, not via my publications but via the subsequent publications of others. As a result, the most important part of what I discovered got permanently ignored. It is still ignored by work on the mind-body problem by philosophers today.

In Chap. 1, I give an account of my early work on the mind-body problem. In Chap. 2, I discuss its reception – the way in which snippets of this work came to have an immense impact via the work of others published years after my publications, but the main body of what I put forward was ignored, and still is ignored, to the cost of subsequent philosophy. I describe how later work of mine on the mind-body problem, published in the years 1984 to 2001, developing my earlier work, has also been neglected. And I bring this work up to date by giving an account of my latest contributions to the mind-body problem.

The second wave of my early work on the metaphysics of science began around 1968. It began with a criticism of Karl Popper. In one way, Popper was a revolutionary; he held that theories cannot be verified in science, only refuted. In another way, Popper was highly traditional; he held the basic aim of science is truth, and the method is to assess theories impartially with respect to evidence. I discovered that this highly traditional idea is false. Physics only ever accepts unified theories even though endlessly many disunified rivals can always be concocted to be even more successful empirically. This persistent acceptance of unified theories only, when endlessly many empirically more successful disunified rivals exist, means that physics makes a persistent metaphysical assumption about the universe: it has some kind of unified dynamic structure. Precisely because this largely implicit assumption is profoundly influential, purely conjectural, and almost bound to be false in the specific form in which it is held at any stage in the development of physics, it is vital

that it is made explicit within the context of physics, so that it can be critically assessed, so that alternatives can be developed and assessed, in the hope of improving the assumption that is made. All this leads, I discovered, to a new conception of science, and a new kind of science, which explicitly acknowledges the profoundly problematic aims of science and seeks to improve aims and associated methods, as science proceeds. I published this work in two papers, “A Critique of Popper’s Views on Scientific Method” (1972) and “The Rationality of Scientific Discovery” (1974).

It then dawned on me that this discovery about the irrationality of current orthodox conceptions of science, and the need to develop a new conception and kind of science which acknowledges the real, problematic aims of science and seeks to improve aims and methods as science proceeds, has momentous implications for the whole academic enterprise. Judged from the standpoint of helping to promote human welfare, academic inquiry devoted in the first instance to the pursuit of knowledge is damagingly irrational in a wholesale, structural way. And this damaging structural irrationality of humanity’s institutions of learning is, in part, responsible for the genesis of our current grave global problems and our current incapacity to resolve them. We urgently need to bring into existence a new kind of inquiry that has, as its basic intellectual aim, wisdom and not just knowledge – wisdom being the capacity, active endeavour, and desire to realize what is of value in life, for oneself and others, wisdom including knowledge, technology, and understanding, but much else besides. A basic task of the new kind of academic inquiry would be to help humanity improve aims and methods of great social endeavours – industry, agriculture, politics, the media, the law, economics – so that we may gradually make social progress in seeking to attain the profoundly problematic aim of a good world.

Granted that a proper basic aim of academia is to help promote human welfare, a basic task must be to (1) articulate, and try to improve the articulation of, our problems of living, and (2) propose and critically assess possible solutions – possible actions, policies, social arrangements, institutions, ways of living, philosophies of life. Inquiry as it is at present, devoted primarily to the pursuit of knowledge, cannot do this. It gives intellectual priority to tackling problems of knowledge, not problems of living. Modern science and technological research, pursued in this way, have been a mixed blessing. They have led to great benefits. They have made the modern world possible. But they have also made possible the development of almost all of our current global problems that threaten the future of humanity and our world. Science and technology have made possible modern industry, agriculture, and fishing, modern hygiene and medicine, and modern armaments, which in turn have made possible population growth; destruction of natural habitats; loss of wild life and rapid extinction of species; the lethal character of modern war; the threat posed by nuclear weapons; immense inequalities in wealth and power around the globe; pollution of earth, sea, and air; and perhaps, most serious of all, the impending disasters of climate change. We need to learn how to solve these immense problems. For that, we need in place institutions of learning rationally designed and devoted to the task. It is just that that we do not have at present. Indeed, academia as it exists at present, devoted in the first instance to acquiring knowledge and technology, is almost designed to help make matters worse, its past intellectual successes a part of what has made our current problems possible in the first place.

This discovery – or apparent discovery – that academia as at present constituted is an intellectual and humanitarian disaster, there being an urgent need for an academic revolution if humanity is going to be able to resolve the grave global problems that threaten its future, struck me as being of such overwhelming importance that I felt I was obliged to devote myself to doing what I could to communicate it to my fellow philosophers, to academics, and to the public at large. After a protracted struggle, I managed to get two books and a paper published: *What's Wrong With Science?* (1976), “Science, Reason, Knowledge and Wisdom: A Critique of Specialism” (1980), and *From Knowledge to Wisdom* (1984). The last work in particular spelled out the argument in considerable detail. It was widely and favourably reviewed at the time. It received a glowing review in *Nature*. And then was forgotten. And despite a steady flow of books, papers, and lectures on the subject since, right up to the present, I have still failed, even today, to get the idea across to the academic world and to the public.

Aside from a few who think well of my work, most philosophers ignore it. There is here a paradox. My books over the years have met with critical acclaim, but the main body of philosophy proceeds as if my publications simply do not exist.

A major reason for this, I believe, is the failure of my early work to get the credit that it deserved. If it had got the attention received by the work of others who merely echoed snippets from my earlier publications, I would have had no difficulty in getting due attention paid to the vitally important argument that we need to transform academia if humanity is to learn how to resolve the grave conflicts and global problems that threaten our future.

In this book, I try to set the record straight. In Part II – Chaps. 3 and 4 – I spell out the second wave of my work on the metaphysics of science about the need to transform science so that it acknowledges and seeks to improve metaphysical assumptions concerning the unity or physical comprehensibility of the universe as an integral part of scientific research. Since around 2007, a burgeoning new field of research in philosophy has come into existence, called “the metaphysics of science”. Very strikingly, this work, from 2007 to the present, ignores my earlier work completely, very much to its cost. My earlier work, as I have tried to indicate, has revolutionary implications for the whole way one conceives of and approaches the metaphysics of science: and yet it is ignored.

Parts I and II are independent of one another to a considerable extent, so that Part II can be read without it being necessary to read Part I first.

In the final chapter, I say something about the most important aspect of all of this, the urgent need to transform our universities, our institutions of learning, so that they become able to help humanity learn what it so desperately needs to learn: how to resolve conflicts and problems of living in increasingly cooperatively rational ways.

Finally I would like to thank Professor Otávio Bueno, Editor-in-Chief of the Synthese Library Book Series, for the invitation to write this book as a contribution to the Synthese Series.

For my good friend Mathew Iredale

Acknowledgements

Pages 161–167 of Chap. 4 are a slightly modified version of an article that first appeared in *Acta Baltica Historiae et Philosophiae Scientiarum*, vol. 5, no. 2, 2018, pp. 108–115; I am grateful to the editor of the journal, Peeter Mürsepp, for permission to republish the article.

Part I of the [Appendix](#), pages 189–203, was first published in N. Maxwell, *The Human World in the Physical Universe*, Rowman and Littlefield, Lanham, 2001, Appendix 2, pp. 259–273. I am grateful to the publisher for permission to republish this material.

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Part I
The Human World/Physical
Universe Problem

Chapter 1

Early Work on the Metaphysics of Science



Abstract The first phase of my work on the metaphysics of science resulted in an MA thesis that was completed in 1965, and three papers extracted from the thesis published in 1966 and 1968. These papers tackled the problem of how to reconcile the world as depicted by physics with the world of common sense – the world as we experience it. A key idea is that physics is concerned only with a highly specialized aspect of all that there is, the causally efficacious aspect. I argued in one paper that Hume was wrong to deny that necessary connections cannot exist between successive states of affairs. On the contrary, we can interpret physics in such a way that it may, one day, specify what exists at one instant that necessitates what exists subsequently, necessity here having all the force of logical or analytic necessity. Given that physics is concerned only with this highly specialized aspect of everything – the causally efficacious aspect – we should not be surprised that other aspects exist about which physics says nothing. Such aspects exist – the experiential aspects of things, both perceptual features of things external to us, and mental aspects of brain processes going on inside our heads. In order to know about the experiential aspects of things – colours, sounds, smells – we need to have had, at some stage in our lives, experiences of these things. No special sort of experience is required, however, in order to understand physics. This means physics cannot predict the experiential. But physics does not need to predict the experiential in order to carry through its predictive and explanatory tasks. Since physics is specifically designed to avoid referring to the experiential, its failure to do so provides no grounds whatsoever for holding that the experiential does not really exist or, if it does exist, it is inherently inexplicable. All this goes some way towards solving the philosophical part of the mind-body problem.

1.1 Outline

In this book I tell the tale of a life-long research project into the metaphysics¹ of science, and into its broader implications: the development of a kind of inquiry best able to help us make progress towards a wiser, more civilized world. I examine the impact – or rather the lack of impact – of the results of this research project on the work of contemporary philosophers.

My work on the metaphysics of science fell into two phases. The first phase, published in my MA thesis and three papers of 1966 and 1968, tackled the problem of how to reconcile the world as depicted by physics with the world of common sense – the world as we experience it. The second phase arose in part out of a critical look at Karl Popper's falsificationist conception of scientific method. Theoretical physics only ever accepts *unified* theories, even though endlessly many empirically more successful disunified rivals are always available. This means, I decided, that physics makes a big, highly problematic metaphysical assumption about the nature of the universe: it exhibits some kind of underlying unity. Because this assumption exercises a major influence over physics and, in the specific version accepted at any stage in the development of physics, is almost bound to be false, it needs to be made explicit within physics so that it can be critically assessed, and so that alternatives can be developed and criticized, in the hope that the assumption adopted can be improved. The best way to do this, I argued, is to make a hierarchy of metaphysical assumptions concerning the comprehensibility and knowability of the universe, these assumptions becoming increasingly insubstantial and so increasingly likely to be true, and more nearly such that their truth is required for science to be possible at all, as one goes up the hierarchy. In this way, a framework of relatively unproblematic assumptions and associated methods is created, high up in the hierarchy, within which relatively problematic assumptions and associated methods, low down in the hierarchy, may be critically assessed and improved, in the light of what seems best to promote the empirical growth of scientific knowledge and other factors. We need, in short, to adopt and implement a new conception of scientific method which improves the aims and methods of science as science proceeds. Furthermore, I argued, this aims-and-methods improving conception of scientific method, when generalized, leads to a new aims-and-methods improving conception of rationality which has major, fruitful implications for academic inquiry as a whole, and for all worthwhile human endeavours with problematic aims.

In the rest of this chapter, I expound the first phase of my work on the metaphysics of science. In Chap. 2, I discuss subsequent work on the subject by others, its failure to take my earlier work into account, and the adverse consequences that flow from this failure. In Chap. 3 I expound in more detail the second phase of my work

¹Throughout the book, as far as I am concerned, a thesis is *metaphysical* if it is about the world and is neither empirically verifiable nor falsifiable. It may be empirically *fruitful*, however, as we shall see in Chap. 3.

on the metaphysics of science, and in the rest of the book I discuss subsequent work on the subject, and the way it suffers from neglect of my earlier work.

In seeking to highlight the potential fruitfulness of my work on the metaphysics of science, roughly from 1966 to 1998, I have been led to stress that subsequent work on the metaphysics of science has suffered in places from its failure to take into account my earlier work. I want to make clear, at the outset, however, that on one key point I am in absolute agreement with almost all of this subsequent work, namely that metaphysics, in order to be done properly, must be done in a scientifically enlightened way. I agree entirely with those who argue that metaphysics pursued in a way which is detached from science does not deserve serious consideration. Indeed, it is a part of my case for the fruitfulness of the new conception of science that I have argued for – *aim-oriented empiricism* – that metaphysics and physics need to be brought much closer together into one integrated enterprise of natural philosophy. Imaginative and critical exploration of metaphysical doctrines needs to be undertaken as an integral part of theoretical physics itself. My neglected work on the metaphysics of science has, I believe, immensely fruitful implications for this branch of philosophy. There is a whole world of intellectual issues and problems out there awaiting exploration and discussion which at present is ignored because the doctrine I defend – aim-oriented empiricism – is ignored. Adopt aim-oriented empiricism, and the whole field of the metaphysics of science really is transformed in an immensely fruitful way – as I attempt to indicate at the end of Chap. 4.

My criticisms, then, are intended to highlight potentially fruitful research for the future, at present neglected, that the metaphysics of science might well undertake. I hope my criticisms will be received in that positive spirit.

1.2 Origins

It began when I was a child, and I decided I had to discover what kind of universe this is. Around the age of 9–11 or so, it seemed to me to be an absolute disaster to live and die, and never discover what sort of world we live in. History was, for me, a tale of wasted lives. All those poor people in the past had lived and died, never knowing what sort of universe this is. Avidly, I read up the then current popular literature on what theoretical physics had to say about the nature of the universe: James Jeans, Arthur Eddington, Fred Hoyle. Reality, I learnt, is very, very different from the way it appears to be. Everything is made of atoms, minute solar systems, but mostly empty space. And the particles which go to make up atoms – electrons, protons and neutrons – are not really particles at all, I discovered, but rather “waves of probability” as Jeans put it somewhere. The tangible world dissolves into mystery. And strange things happen if you move fast: time slows down, distance shrinks, and things become massive. And weirdest of all, gravity turns out not to be a force at all; it is rather curvature in space – or in space-time for, according to Einstein’s theories of relativity, so it seems, space and time had to be fused together to form

one entity, variably curved space-time. The discovery of the ultimate nature of the universe would be a profound revelation for us all.

But then adolescence came along, and I decided it was far more important to understand *people* than *the universe*. Hoyle declared that when theoretical physics discovered the truth about the nature of the universe, it would be possible to write it down on a postage stamp in a set of equations – or words to that effect. But that would leave everything that really mattered unknown, it seemed to me: the inner realities of people's lives, their secret feelings, desires, thoughts, the mystery of the human soul. And the way to understand people, it seemed to me, was by means of literature, above all the novel. Not for a moment did I think psychology would be relevant. I was fortunate; my parents possessed works of world literature translated into English. I devoured Dostoevsky, Chekhov, Stendhal, Flaubert, Kafka, Tolstoy, Virginia Woolf, Henry Fielding, Thomas Hardy, D.H. Lawrence. And I recognized my passions and confusions in these works. I was one of them. I would write novels and lay bare the secrets of the human heart and soul as it had never been done before.

But when it came to trying to write, I found I could not solve the problem of telling lies in order to tell the truth. Mr. Timpson left his home early that day, so eager was he to get to work. Thus might a novel begin. But how could truth about the human heart come out of anything like that, when there was, in reality, no Mr. Timpson, no home, no wife waving him good bye, no office he was eager to get to? It was all just naked fabrication.

Having failed miserably as a theoretical physicist (before I had even started), and having failed miserably as a novelist, I decided, eventually, to go to Manchester University to study philosophy. I had, for some time, been reading books on philosophy: *An Introduction to Philosophy* by W.A. Sinclair; *A History of Western Philosophy* by Bertrand Russell; *Some Main Problems of Philosophy* by G.E. Moore, *The Problem of Knowledge* by A.J. Ayer. Sinclair's book introduced me to the British empiricists: Locke, Berkeley and Hume. I learnt, in particular, from reading about Hume, that we could not be absolutely confident that the sun would rise tomorrow. Hume, I realized, was right. I had thought the universe would never dare disobey the august authority of all those scientists of the Royal Society: it would have to comply with the physical laws they had discovered. What could be more absurd? It must always be possible for the universe to surprise us. We cannot justifiably claim to have secure scientific knowledge about it, authoritative dominion over it as it were. Here, in connection with Hume, there was a nugget of truth and insight – one which I was rather ashamed not to have thought of myself. As for the rest of it, I was not impressed. Philosophy could not remotely hold its own against theoretical physics, and literature. Nevertheless, I had been thinking about the issues: I would go to Manchester to study for philosophy for three years, and then I would join the grey shuffle of ordinary, uncreative life. In those days, for me, the only life worth living was a life devoted to the creation of something startling, new and profound; the rest of it was without much interest. O the self-destructive arrogance of youth!

Philosophy, I discovered, was a subject I seemed to be rather good at. In my first week as an undergraduate, Professor Arthur Prior set us, as an essay topic, “Do we see stars?”. I thought about it, spelled out arguments for and against, and handed my essay in. The question arises, of course, because light from a star may take so long to reach us that when we “see” the star, it may no longer exist. How can you see an object which does not exist?

When he handed my essay back to me, Prior said that he had set the question as an essay topic for a prize for academic philosophers. He said my essay included all the arguments that had been put forward in essays of the competition, and no single essay of the competition had included all of my arguments. Prior then told me about an article that had just been published in *Mind* about J.M. McTaggart’s argument about the unreality of time. I read the article, decided it was wrong, and spelled out why in my essay. Prior handed it back to me, and said “I think you are right”. I was flabbergasted. Here I was, in my second week as a fledging undergraduate, and already I was at the coal face of research in philosophy.

Later that year Prior asked us to write an essay about the mind-body problem. I thought hard about it, and decided that standard reasons for holding we know all about our inner experiences, and certainly enough to know they are not brain processes, are wrong. It occurred to me that we may know more about the world around us than we do about what is going on inside our heads. Perhaps we do not know enough about our inner experiences to know that they cannot be brain processes. When he handed my essay back to me, Prior asked me rather sharply what I had been reading. I confessed I had not read anything; I had just gone for walks and thought about the problem. Later, I realized why he had asked me; his friend, J.J.C. Smart had only recently published his paper “Sensations and Brain Processes” 2 years earlier in 1959.

But after my first year doing undergraduate philosophy, I fell into despair. I became entangled in thickets of contradictory philosophical arguments and impulses. On the one hand, there was Cartesian dualism, which to me implied that we are locked away inside our minds, mind-stuff being utterly distinct from the physical world. This could not be right: but what alternative was there? On the other hand, there was Hume’s argument about the impossibility of one state of affairs determining necessarily what comes to exist next. If Hume were right, anything may happen at any moment. We have no right to expect established regularities will continue to be observed. That is absurd – and yet Hume’s argument seems decisive.

When the Summer holidays began, I took a job working in a factory during the day, and in the evening began to write – I had not yet entirely abandoned my hopes of becoming a novelist. I also started a diary, in which I explored my tangled hopes and desires. Out of this diary writing came intellectual and emotional explosions which transformed my life and led to the research project that is the subject of this book. Cartesian dualism is wrong, I decided. We are not locked away in our minds inside our skulls. What is within us is as much a mystery as what lies without. What we are – our identity – is not what lies within us; it is the interchange between what is within and what is without. We are as much a part of the world around us as we

are of the world within us. The world as we experience it really does exist; it is not all inside our heads. “The riddle of the universe” I wrote down in my diary “is the riddle of our desires”. What is of most value in life? That, I decided, is the proper fundamental problem of philosophy. I returned to Manchester in the Autumn with the intention of telling the Philosophy Department of my exciting philosophical discoveries. I found I could not open my mouth.

The third year undergraduate course was devoted to ordinary language philosophy: Wittgenstein, Austin, Ryle. The idea is to solve philosophical problems by analysing the way words are used. “What is the nature of reality?” is to be answered by an analysis of the way the word “real” is used in ordinary life. This approach to philosophy struck me as a denial of philosophy – “anti-philosophy” as I came to call it. “What is the nature of reality?” can arise as a profound philosophical problem because there are two dreadfully clashing theories about the nature of the world around us, what physics tells us, and what common sense and ordinary experience tell us. Both deserve to be taken seriously, but both cannot, it seems, be right. The question about the nature of reality asks whether the world really is made up of atoms, electrons and protons, waves of probability, or the trees, houses, green fields, people and houses that we see. Austin’s discussion of “the Nature of Reality” in terms of dyed hair, paste diamonds and decoy ducks trivializes – or rather negates – the problem.² I decided not to attend lectures on this stuff, fearful that if I did I would become brainwashed into thinking it was a legitimate way to proceed. Analytic philosophy, I decided, rests on a dreadful mistake. The proper way to proceed is to try to get clear about serious problems (which may not initially be well-formulated), and then solve them.

The only part of the third year course that interested me was that part devoted to philosophy of science. Philosophy might be trivial, but science clearly matters, and perhaps some of its significance might rub off on the philosophy of science. But this course was run by Wilfred Mays who only wanted to talk about the Babylonians, when what interested me was whether electrons really exist or not. In the end, I had to take over the seminar (there were only two of us doing the course) so that the ontological status of electrons might be discussed.

1.3 Physics and Common Sense

Despite my non-attendance at lectures, the Manchester Philosophy Department was sufficiently generous to give me a II(i) for my degree. That made it possible for me to do an MA in philosophy. Haunted by the problem of the clash between the world of common sense, and the world as depicted by modern physics, I decided the solution to the problem was not to take any one view too seriously. There are many diverse myths; the mistake is to regard only one as constituting *truth*. My thesis

²Austin (1962, chs. VII–VIII). I take up the topic of conceptual analysis again in Chap. 4, and in the [Appendix](#).

would be about myths. But my supervisor, Ted Dawson, insisted I had to cut the myths down to two: physics and common sense. Then I came across Karl Popper, and I was struck by the following passage.

The belief of a liberal – the belief in the possibility of a rule of law, of equal justice, of fundamental rights, and a free society – can easily survive the recognition that judges are not omniscient and may make mistakes about facts and that, in practice, absolute justice is hardly ever realized in any particular case. But this belief in the possibility of a rule of law, of justice, and of freedom, can hardly survive the acceptance of an epistemology which teaches that there are no objective facts; not merely in this particular case, but in any other case: and that the judge cannot have made a factual mistake because he can no more be wrong about the facts than he can be right.³

I was ashamed of myself. Popper was of course right. Without fact and truth, justice collapses. Truth is infinitely too important to be dispensed with. I would have to rethink my truth-denying resolution of the physics/common sense problem.

I then discovered another book that was very helpful: J.J.C. Smart's *Philosophy and Scientific Realism*. Smart courageously ignored the reigning fashion of conceptual analysis and laid out his answer to the question "What is the nature of reality?". The answer is: physics. Theoretical physics provides us with our best account of what there is, what kind of universe we are in. Only the physical really exists. Anything which is such that it cannot, in principle, be predicted by physics, does not exist. Not for one moment did I think Smart's view of things sufficed. But I welcomed its trenchant clarity, its freedom from customary philosophical nonsense. And the insight that we only know about our inner sensations via our knowledge of the perceptual properties of things external to us struck me as brilliant. What does a person know about a yellowish-orange after-image he is experiencing? "*What is going on in me is like what is going on in me when my eyes are open, the lighting is normal, etc., etc., and there really is a yellowish-orange patch on the wall.*"⁴ Our knowledge of our inner sensations, in other words, is derived from our prior perceptual knowledge of things external to us. This poses a problem for the hard-line version of physicalism that Smart defends, according to which perceptual qualities, in so far as they exist, are just purely physical properties. It does not, however, pose a problem for the *experiential* version of physicalism I was about to develop, in effect a version of the two-aspect view. Smart's book was, in any case, enormously helpful to me from the standpoint of writing my MA thesis. It gave it a focus: I could criticize Smart. The full title is in fact *Physics and Common Sense: A Critique of Physicalism*.⁵

As a result of discovering the passage quoted above from Popper, I decided that, in order to solve the problem of the clash between the physical universe and the world of common sense as we experience it, physics had to be interpreted as seeking to depict, not everything about everything, but rather only *a highly selected aspect* of everything. As a result, the silence of physics about the experiential does not

³Popper (1963, p. 5).

⁴Smart (1963, p. 94).

⁵MA thesis, 1965, University of Manchester Library.

mean that the experiential does not exist. It just means that the experiential aspect of things is not the kind of aspect that physics seeks to depict. Both depictions of the physical universe *and* depictions of the common sense, experiential world can be *true!* Truth and fact do not need to be sacrificed to resolve the clash between physics and common sense.

At once the questions become: *What* aspect of the world precisely is physics concerned to depict? And *why* exactly is physics not able to depict and predict the experiential aspects of things? In what follows, I assume that physicalism is true. That is, I assume that the world is such that there is a yet-to-be-discovered physical “theory of everything”, T, which in principle, but not in practice, is capable of predicting all physical phenomena. The crucial questions are: What precisely does T depict? Why exactly is T not able to predict the experiential aspect of things?

1.4 Physical Essentialism

Physics, I decided, is concerned to depict what may be called the *causally efficacious* aspect of things – that aspect that exists, at any instant, that determines, necessarily, what exists at the next instant. Ordinary, so-called dispositional properties, such as solid, sticky, opaque, transparent, inflammable, hard, soft, carry implications about how things change, or do not change, in certain circumstances. Physical properties are the same, except that they are much more precise, and far more widely present in the world. Mass, electric charge, momentum, angular momentum, gravitational charge: all these properties determine how physical entities interact and evolve, as time passes, from moment to moment.

It struck me, however, that very precise conditions must be satisfied if what exists at one instant is to determine, necessarily, what exists at the next instant. In declaring that a *logically necessary connection* exists between two successive physical states of affairs, we are of course asserting that such a connection exists between the description or specification of the first state of affairs, and the description or specification of the second state of affairs. The logical connection is between *propositions*, not *events*. But if stringent conditions are satisfied, we can say that the logical connection between the specifications of the two events enables us to say that there is a *necessary connection* between the events.

What we require is that the propositions which specify the first event do no more than specify the first event – so that if any content whatsoever is removed from these propositions, then something of what exists when the first event occurs is no longer described or specified. The propositions thus *do no more* than specify what exists at the time of occurrence of the first event. If, granted that these conditions are satisfied, and still these propositions logically entail what exists next, then we can declare that there is a necessary connection between the two events or states of affairs. It is not logically possible for the first event to exist, and the second event not to occur subsequently.

All this can be illustrated by considering a Newtonian universe, composed of Newtonian particles. There are, let us suppose, at the first instant, time t_1 , just three Newtonian particles, each having a precise position and velocity, each possessing a precise mass, the inertial mass, m , being equal to the gravitational mass g . If two particles possess gravitational masses g_1 and g_2 , then, of necessity, there is an attractive force, F , between them, where $F = Gg_1g_2/d^2$, where G is the constant of Newton's law of gravitation, and d is the distance between the particles. It is built into the *meaning* of Newtonian gravitational charge, g , in other words, that particles which possess this physical property must, necessarily, obey Newton's law $F = Gg_1g_2/d^2$. If they do not obey Newton's law then, *ipso facto*, they do not possess the physical property of Newtonian gravitational charge.

The three particles we are considering also possess the necessitating physical property of Newtonian inertial mass. A particle that possesses such a property, m , of necessity obeys Newton's law $F = ma$ where a is acceleration.

In order to specify what exists in our Newtonian universe at time t_1 , we need to specify the instantaneous positions and velocities of the three particles; we need to specify that they possess Newtonian inertial and gravitational masses, m_1, m_2, m_3, g_1, g_2 and g_3 , with $m_r = g_r$ for $r = 1, 2, \text{ and } 3$; and we need to specify that the rest of space is everywhere empty (a necessitating physical property being possessed by empty space which is such that it necessarily determines, at each point, that empty space gives rise to empty space unless an already existing particle is in motion from one place to another).⁶ Such a specification suffices to entail logically propositions that specify what exist next – and what exist at all subsequent instants in this rather sparse Newtonian universe.

It may be objected that propositions that specify what exists at time t_1 and, supposedly, logically entail propositions that describe subsequent states of affairs, include more than just descriptions of what exists at time t_1 . For these propositions include the laws $F = Gg_1g_2/d^2$ and $F = ma$. But these laws are to be interpreted *essentialistically*. All they do is spell out what it means to attribute Newtonian gravitational charge and inertial mass to bodies. Just as the analytic statement "All bachelors are unmarried" does not, in a sense, contain any information but simply spells out what "bachelor" means, so too these laws do not contain any information but simply spell out what "Newtonian gravitational charge" and "Newtonian inertial mass" mean. The laws are purely *analytic propositions*, devoid of empirical content.⁷

⁶As I conclude in Maxwell (1968a), only a true theory of everything that is a field theory can depict necessary connections between successive states of affairs.

⁷An analytic proposition is one which is true in virtue of the meaning of constituent terms. An example is the one given in the text, "all bachelors are unmarried", which must necessarily be true as long as it is built into the meaning of "bachelor" that a bachelor is an unmarried man. In an inexplicably famous article, Quine (1963) casts doubt on whether a sharp distinction can be drawn between analytic and synthetic statements (the latter being genuinely factual statements which make factual assertions and cannot be true necessarily). But Quine's arguments fail to establish the point. They apply to *sentences*, and sentences, and the constituent words of sentences, can change their meaning from time to time, and from context to context. The analytic/synthetic distinction applies to *propositions*, not sentences; the former, unlike the latter, are stipulated (as it were) to

One can, of course, assign looser meanings to “gravitational charge” and “inertial mass” so that the above laws are not implicit in the meaning of these terms. (Laws of some kind will, however, be implicit in the meaning of the terms. For example, “gravitational charge” might be so interpreted that the following is implicit in the meaning of the term, and is analytic: “Two gravitationally charged objects are attracted towards each other by means of a force that depends, in some fixed way, on the values of the charges and the distance between the two objects”.) The crucial point however is this. If the state of affairs at time t_1 is described by means of gravitational charge and inertial mass, given these vaguer meanings, then an aspect of what exists at t_1 is no longer described. These terms with these vaguer meanings are insufficiently precise to specify fully what exists at time t_1 .⁸

There is a very obvious and apparently lethal objection to what has been argued for so far. According to the above account, necessary connections between successive states of affairs can only exist if the relevant physical theory is interpreted *essentialistically*, and that requires that the physical laws of the theory are interpreted as *analytic statements*. But this is nonsense! Physical laws cannot be *analytic*. They have empirical content, they are empirically falsifiable, and a vast number, put forward since Galileo, let us say, have been decisively refuted. Besides, if the laws of physical theories are analytic, that would mean physical theories are too, which is clearly all too patently false.

My reply to this objection is as follows. Physical theories *can* of course be interpreted in such a way that the physical laws they embody are factual and empirical, as I have indicated above. All we need do, to arrange for this outcome, is to interpret relevant terms of the theory in question sufficiently loosely, so that *some*, perhaps rather vague law-like propositions are implicit in the meaning of the terms in question, but not the full, precise laws of the theory. (Above I indicated how “gravitational charge” and “inertial mass” can be interpreted in a vague way, along these lines.)

We are not *obliged* to interpret physical theories in this sort of way however. As long as a theory can be interpreted realistically, as specifying laws governing postulated physical entities which, together with initial (and boundary) conditions, predict in principle how the postulated entities interact and evolve, such a theory can be

have definite, fixed meanings that do not change from time to time, context to context. Quine’s arguments, decisive against *sentences*, are simply inapplicable when it comes to *propositions*. It should be noted that in mathematics and physics, “analytic” has a quite different meaning from the one the word has in philosophy. An analytic function is one that is infinitely differentiable and can be represented as a Taylor series.

⁸One objection that has been raised to the possibility of Newtonian theory being interpreted in a fully essentialistic way, with all the laws interpreted as analytic propositions, is that in that case we would not be able to understand what the key terms, such as “gravitational charge”, “inertial mass”, and “force” *mean*. But this does not pose a problem. We may take Newtonian theory given its ordinary interpretation, the meaning of which can be understood, and then progressively modify these meanings so that more and more factual, lawful content is built into the meaning of these terms, until the laws of Newtonian theory become true analytically. Because we can understand the meaning of the Newtonian terms given that the theory is interpreted in the usual way, we can also understand these terms when much more factual content is built into the meaning of these terms.

interpreted essentialistically, as attributing what may be called *necessitating physical properties* to the physical entities in question. We may interpret such a theory in the way I indicated the Newtonian theory can be interpreted above.

But how can such a theory be *factual* and *empirical* if all its laws are analytic? The answer is very simple. All the empirical content of the theory is concentrated in some such assertion as: there exist physical entities with such and such physical necessitating properties. Or: the world is made up exclusively of physical entities with such and such physical necessitating properties. The entire factual, empirical content of the theory is contained in this existential statement – as I made dazzlingly clear in my 1968 paper.⁹ It is this existential statement which will, in all probability, be empirically falsified, and turn out to be false. A Newtonian theory that asserts: the world is made up exclusively of particles that possess Newtonian gravitational charge is refuted by the observation that repulsive forces exist between bodies – electric and magnetic.¹⁰ It is refuted by the observation that cohesive forces exist, which hold macroscopic bodies together – difficult to account for in terms of Newtonian gravitational charge!

A slight problem does arise in connection with refuting empirically a pure existential statement. In order to refute the statement that such and such an object exists one would need, it seems, to examine the entire universe, to ensure it does not exist anywhere. But the assertions of existence of essentialistically interpreted theories are not *pure* existence statements, bald statements that such and such a kind of entity exists. Rather, the theory will assert that a range of specified phenomena are composed of such and such physical entities. Such an assertion might be: material bodies are composed of atoms, in turn composed of electrons, protons and neutrons, the latter two entities in turn composed of quarks and virtual gluons. The standard model – the current fundamental physical theory of fundamental physical entities and the forces between them – does not just assert: electrons and quarks exist. If it did, it would render the theory (essentialistically interpreted) irrefutable. Rather, it asserts that all the material stuff around us, and visible in the heavens, is composed of electrons and quarks (and the virtual particles associated with the forces that act between them). Thus an essentialistically interpreted theory asserts that specified ranges of phenomena are composed of physical entities postulated by the theory; the outcome is that the theory becomes empirically testable.¹¹

⁹In the paper I formulated a toy “theory of everything”, T, consisting of six postulates, (i)–(vi), specifying laws, interpreted as analytic propositions, and one final existential statement asserting “(vii) The world consists entirely of particles mass m , charge $+q$, unstressed radius r , elasticity E ”: Maxwell (1968a, p. 19). And I went on to point out that “the fact that the postulates (i)–(vi) of T are analytic does not mean that T itself is analytic, for of course (vii) is non-analytic. The entire empirical content of T is contained in the postulate (vii)”: Maxwell (1968a, p. 20); see also p. 22, where the statement is repeated!

¹⁰Let us ignore quibbles that involve the invention of *ad hoc* hypotheses that save the theory from refutation!

¹¹Precisely this solution to the problem was sketched in my (1968) paper: see Maxwell (1968a, pp. 22–3).