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PHILOSOPHY AND THE PHYSICISTS

BY THE SAME AUTHOR

A MODERN INTRODUCTION TO LOGIC

LOGIC IN PRACTICE

PHILOSOPHY AND THE PHYSICISTS

BY

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TO

MARGARET WILLIS

PREFACE

THIS book is written by a philosopher for other philosophers and for that section of the reading public who buy in large quantities and, no doubt, devour with great earnestness the popular books written by scientists for their enlightenment. We common readers, to adapt a phrase from Samuel Johnson, are fitted neither to criticize physical theories nor to decide what precisely are their philosophical implications. We are dependent upon the scientists for an exposition of those developments which—so we find them proclaiming—have important and far-reaching consequences for philosophy. Unfortunately, however, our popular expositors do not always serve us very well. The two who are most widely read in this country are Sir Arthur Eddington and Sir James Jeans. They are not always reliable guides. Their influence has been considerable upon the reading public, upon theologians, and upon preachers; they have even misled philosophers who should have known better. Accordingly, it has seemed to me to be worth while to examine in some detail the philosophical views that they have put forth and to criticize the grounds upon which these views are based.

Sir Arthur Eddington stands in no need of commendation by me. Indeed, for me to praise him is almost an impertinence. But so much in this book is adversely

how great is my admiration for his scientific work. Although my understanding of his *Mathematical Theory of Relativity* and his *Relativity Theory of Protons and Electrons* is very defective, I have derived from studying them a profound delight. They seem to me to have a form and completeness which is, perhaps unavoidably, absent from most first-rate contributions to physical science published to-day. The rapidity of development in physics—which makes a theory out of date almost as soon as it is published—no doubt makes it difficult, and in many cases impossible, to give to works on physical science that completeness and beauty of form which is found in such great works as Galileo's *Dialogues concerning the Two Great Systems of the World* and Newton's *Principia*. But this beauty of form I, at least, find in Eddington's two great books. He has, I think, pre-eminently what has been called 'the synoptic mind'. Accordingly, his writings are naturally attractive to a philosopher of my generation.

The difficulty presented to the common reader by Sir Arthur Eddington's philosophical writings is due to the fact that he is not only a great scientist but has also wide and deep interests beyond the bounds of science, whilst his strong philosophical bent makes him anxious to connect his philosophy of science with his philosophy of life at all costs. The cost is greater than he seems to have realized. He is so great a scientist that it may seem a mere absurdity for a rather incompetent philosopher to criticize him. But his greatness as a scientist is to be judged not by the books I have discussed but by his strictly scientific works that stand in as much need of being interpreted for the benefit of the common reader as do the works of any other scientist. In the books

with which I have mainly been concerned, Eddington has set forth for the benefit of the common reader an interpretation of recent developments in physics, including his own contributions in this domain. His interpretation, however, suffers from very serious omissions and from an altogether misleading emphasis. One of the most striking omissions is his failure to give the common reader any indication as to the way in which physical measurements are in fact obtained. This omission enables him to produce the paradox that physics is solely concerned with pointer-readings. His very skilful, and frequently amusing, mode of presentation has enabled him to throw the emphasis upon just those elements which are most essential for the development of his metaphysical views. His lack of philosophical training (which I deduce from his writings, not from any private information as to his reading list) has made it possible for him to slip into pitfalls that he might otherwise have learnt to avoid.

The belief that the 'new physics' is favourable to some form of philosophical idealism has caused much alarm to Lenin and other leaders of Russian Communism. As long ago as 1908, Lenin wrote: 'On the side of materialism there is the large majority of scientists in general, as well as in that special field, namely, of physics. The minority of modern physicists, however, under the influence of the crisis in the old theories (due to the great discoveries of recent years), and under the influence of the crisis in the new physics (which clearly revealed the relativity of our knowledge), because of their ignorance of dialectics fell from relativism into idealism. Idealistic physics, which is in vogue just now, is just as reactionary and transitory as the fashionable

idealistic physiology of the recent past.'[1] But it is not by knowledge of 'dialectics' that we shall be saved from idealism, whether 'reactionary' or not. Lenin and other dialectical materialists have as much an axe to grind as any Gifford Lecturer. The 'materialists'—to give them the name which they so ardently admire—seek at all costs to establish some form of metaphysical materialism. Scientific results must somehow or other be forced into an interpretation which will yield the special philosophical views upon which their political philosophy is professedly based. There is as much bad metaphysics and immature philosophizing among the upholders of dialectical materialism (so far as my acquaintance with their writings goes) as among those who support the philosophical idealism of the pulpits. It has not, however, lain within the scope of this book to discuss these ardent philosophers. I would merely guard against a possible misunderstanding. If I have succeeded in showing that the present state of physical theories does not warrant any form of idealism, it must not thereby be concluded that I suppose it to warrant any form of materialism.

I have in this book used the term 'physicist' something too loosely. I might defend myself by appealing to the meaning given by Aristotle to φυσικός, but it may suffice to point out that I use 'physicist' to designate

[1] *Materialism and Empirio-Criticism*, p. 310. The idealists of whom Lenin was primarily thinking were the disciples of Mach, whom he calls 'Machians'. I am inclined to think that he hardly understood Mach's own view. An interesting article bearing on this topic, entitled 'The Mechanical versus the Mathematical Conception of Nature', has recently been published by Prof. P. Frank in *Philosophy of Science*, January, 1937.

any scientist who is concerned in promoting the development of the physical sciences. I make no doubt that Eddington's mathematical colleagues regard him as a physicist whilst the experimental physicists may be inclined to relegate him to the company of mathematicians. No sharp line can be drawn—in which fact the instructed reader may possibly find a clue to the understanding of some recent theories of Nature.

My obligations are many but, for the most part, so indeterminate that I can hardly place them on record. I have been helped considerably, both by way of instruction and provocation, by many of the books I have read and have mentioned in the bibliography. Foremost I would place Professor E. A. Burtt's *The Metaphysical Foundations of Modern Physical Science*, which I read with great profit some years ago and to which I am more indebted than my scanty reference in the text would suggest. I have been privileged to read in typescript the first draft of Professor Herbert Dingle's forthcoming Lowell Lectures, and have further benefited by some discussions with him. My deepest obligation is to my colleague at Bedford College, Professor William Wilson, F.R.S. He read Chapters VIII and IX in manuscript and made many helpful criticisms. He is not, of course, responsible for the errors that remain. Further, he allowed me to read his paper on ' The Nature of Wave-Mechanics ', which is to be published in *Science Progress* in October of this year. The common reader would be well-advised to study it. I am indebted to Professor M. Evelyn Clarke for reading the proofs and for making some valuable criticisms. All these I wish to thank, and others also, too numerous to be named, who have taught

me much in conversation, especially my friend Miss Margaret Willis, who asked me difficult questions, some of which I have tried to answer in this book in a manner worthy of her honesty of mind.

L. SUSAN STEBBING

LONDON, *July 30, 1937*

NOTE

For personal reasons I was prevented from attending at once to the revision of the page proofs and from compiling the index. I am greatly indebted to Dr. Joan W. Reeves who kindly undertook this task in the first place. In the final revision of the proofs I have been much helped by my friend Miss V. S. Shepherd, and in the final compilation of the index by Miss Lillan Chasanovitch. Without the help of these three friends the delay in publication would have been greater. I desire to express to them my grateful thanks.

L. S. S.

September 28, 1937

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ABBREVIATIONS

N.Ph.W.	The Nature of the Physical World
N.P.Sc.	New Pathways in Science
S.U.W.	Science and the Unseen World
M.U.	The Mysterious Universe

Part I

THE ALARMING ASTRONOMERS

'I, a stranger and afraid
In a world I never made.'

A. E. HOUSMAN

Chapter I

THE COMMON READER AND THE POPULARIZING SCIENTIST

Man is but a reed, the most feeble thing in nature ; but he is a thinking reed. The entire universe need not arm itself to crush him. A vapour, a drop of water suffices to kill him. But if the universe were to crush him, man would still be nobler than that which killed him, because he knows that he dies and the advantage that the universe has over him ; of this the universe knows nothing.

PASCAL

THE age in which we are living is pre-eminently an age of scientific discovery. The advance of the sciences is not only rapid but also spectacular. A 'new discovery' in this, that, or the other, branch of science is not only 'News', it is even 'Headline News'. The physical sciences, scarcely more than three centuries old, have in the last half-century so rapidly developed that the researches of the physicist and the chemist have profoundly altered for good or for ill the life of nearly every human being. Knowledge gives power ; knowledge of natural occurrences has already given, increasing knowledge will continue to give, men power to alter and to control their environment in ways which, but a short time ago, would have seemed godlike or devilish. The boundaries between the natural sciences have to some extent broken down. The crystallographer, the bio-chemist, the physiologist, may pool their knowledge to

give men health or to devise means of exterminating each other in a new and deadly warfare. There is no need to expatiate upon the changes brought into our lives by machines; these are sufficiently well known and inescapable. Nor is it necessary to emphasize 'the shrinkage of the world' due to more rapid means of communication by air travel and by wireless. Napoleon Bonaparte would no doubt be less bewildered fighting in the company of Edward I than as a general in the Italian Army to-day. That scientists can confer such power wins for them, intelligibly enough, great respect. At a time when the editors of daily newspapers invite film stars, financiers, popular novelists, and explorers to express their views on 'the ultimate questions of life', it is not surprising that eminent scientists should be urged to explain 'the philosophic attitude to which their work has brought them'—to use the label attached to a series of 'Interviews' with scientists reported in the *Observer* some six years ago. Nor is it surprising that even the idle diversions of men of proved scientific attainments should carry weight with the common reader.

In these days of popular expositions, both written and broadcast, of Outlines, and of mammoth Guides to the Intelligent Man—guides through science, guides through economics, guides through philosophy, guides through chaos—the common reader cannot be unaware that the sciences in general and the physical sciences in particular have been developing rapidly and that in the course of this development certain changes, describable as 'revolutionary', have occurred. These developments in science have a twofold interest. First, their results have given us information, often surprising, about the world we live in. Secondly, the following out of scientific method is in itself exciting, affording us the purest of all satisfactions—intel-

lectual satisfaction. There is among common readers a genuine interest in scientific research, a desire to follow as far as a layman can what is being found and to understand the implications of these findings. Some of us are prepared to attempt to make the considerable intellectual effort required in order to understand even a non-technical exposition of recent developments in physics. The writing of such an exposition is undoubtedly difficult. It requires not only great powers of exposition but also an apprehension of the sort of difficulties the layman is likely to find and the skill to surmount them. We can hardly complain if these matters are not made entirely clear to us. Nevertheless, there are not a few scientists who have written books that to some extent satisfy our needs.[1] Unfortunately, however, there are other famous scientists who do not seem to realize that their subject has an intrinsic interest for the common reader, and accordingly they seek to arouse his emotions, thereby inducing a frame of mind inimical to intellectual discernment. Popularizations of such a kind constitute a grave danger to thinking clearly. Possibly the authors themselves are at times wrought up to a pitch of emotional excitement, unduly impressed by the strangeness of their discoveries. I say '*unduly* impressed' because, however strange may be the accounts of recent physical speculations, these physical speculations are themselves the development of the normal procedure of scientific method. The invention of new and more delicate scientific instruments has extended the physicist's range of experience; fresh mathematical techniques have had to be devised to deal with the discoveries thus made. It must not, however, be too hastily assumed that these new instruments and these new mathematical devices constitute in themselves a radical

[1] See Bibliography.

transformation of the nature of our knowledge. Some of our scientific guides, writing in moments of emotional exaltation, have found it easier to mystify the common reader than to enlighten him.

Reflections such as these may well occur to anyone who meditates upon the popularity of the non-technical writings of Sir Arthur Eddington and Sir James Jeans. Both are eminent in their own branch of science. Both are adepts at picturesque exposition. Sir Arthur Eddington is an original thinker of the first rank. Sir James Jeans has shown himself capable of writing lucid and straightforward accounts of our present astronomical knowledge. His books, *The New Background of Science*, *The Stars in their Courses*, and *Through Space and Time*, deserve to be ranked with Sir William Bragg's well-known popular expositions—*Concerning the Nature of Things* and *The Universe of Light*—as admirably designed to inform the common reader. But neither Sir Arthur Eddington nor Sir James Jeans seems to care very much whether his method of presenting his views concerning the philosophical significance of physical theories may not make it more difficult, or even impossible, for the common reader to understand what exactly it is that has been said. Both these writers approach their task through an emotional fog ; they present their views with an amount of personification and metaphor that reduces them to the level of revivalist preachers. Yet we common readers surely have a right to expect that a scientist setting out to discuss for our benefit philosophical problems arising from his special studies will do so in a scientific spirit. He would seem to be under a special obligation to avoid cheap emotionalism and specious appeals, and to write as clearly as the difficult nature of the subject-matter permits. Of this obligation Sir James Jeans seems to be totally unaware,

whilst Sir Arthur Eddington, in his desire to be entertaining, befools the reader into a state of serious mental confusion. These are grave charges to make. It is the purpose of this chapter to attempt to substantiate them.

Both Eddington and Jeans [1] may seem to have forestalled such criticism. Replying to a critic, Eddington says, 'Non-technical books are very often a target for criticism simply because they are non-technical.' He adds, 'I take it that the aim of such books must be to convey exact thought in inexact language. The author has abjured the technical terms and mathematical symbols which are the recognized means of securing exact expression, and he is thrown back on more indirect methods of awakening in the mind of the reader the thought which he wishes to convey. He will not always succeed. He can never succeed without the co-operation of the reader' (*N.P.Sc.* 279). There is much truth in this statement, although Eddington does not show himself to be aware that *exact* thought cannot be *conveyed in inexact language*; at best it can be but partially conveyed, at worst the illusion will be created that it has been conveyed. Eddington seldom aids the reader in co-operating in determining *how* inexactly the thought has been conveyed. He contents himself with remarking that he must not be taken always to mean just what he says. The difficulties thus created for the reader will need to be discussed in detail in later chapters. Jeans does not seem ever to have noticed that his language is inexact, he appears to wish to defend himself from the charge of being a philosopher, thereby perhaps exempting himself from the duty of thinking rigorously.

[1] I hope that this dropping of titles, in future references to these distinguished men, may be recognized as a sign of respect too often withheld until a great man is dead. The practice has also the merit of brevity.

In his book, *The Mysterious Universe*, he sought ' to provide useful material for the discussion of the ultimate philosophical problem '. In the last chapter of the book he presents his own conclusions. With regard to his fitness to discuss these problems he makes a point of saying : ' I can claim no special qualifications beyond the proverbially advantageous position of the mere onlooker, I am not a philosopher either by training or by inclination.' It may be true that the onlooker sees the best of the game, although he can hardly do so unless he knows the rules observed by the players. However that may be, it is absurd to assume, on the basis of this unsound analogy, that one who is not a philosopher either by training or by inclination is in a privileged position in the discussion of philosophical problems. Jeans would resent, and rightly resent, the claim of a philosopher who had no technical knowledge of astronomy to put forward discredited astronomical theories as if they were the outcome of the latest developments of the science. It is odd indeed that he does not seem to see that ' a stranger in the realms of philosophy ' may make a fool of himself, if, having neither training nor inclination, he should try to enter therein. That a similar invasion of science on the part of a mere philosopher would be unwarranted he clearly recognizes. Having laid stress upon ' the widespread conviction that the new teachings of astronomy and physical science are destined to produce an immense change on our outlook on the universe as a whole, and on our views as to the significance of human life,' Jeans continues : ' The question at issue is ultimately one for philosophic discussion, but before the philosophers have a right to speak, science ought first to be asked to tell all she can as to ascertained facts and provisional hypotheses. Then, and only then, may discussion legitimately pass into the realms of philosophy.' This estimate

of the relative positions of the scientist and the philosopher appears to be eminently just. Certainly there are philosophers who need to be reminded of it. There is, however, a certain obscurity—perhaps a certain disingenuousness—in the remark '*science* ought first to be asked to tell all she can'. It suggests a final and higher court of appeal. This suggestion is misleading. Science is not a goddess or a woman. We cannot ask *science*, but only *scientists*. Moreover, we must ask our questions of the scientist at a moment when he is in a scientific temper, capable of giving us 'the ascertained facts and provisional hypotheses' without any admixture of the emotional significance which he reads into these facts in his least scientific moods. The first chapter of *The Mysterious Universe* suggests that Jeans is not the guide of whom we are in need. This point must be stressed if we are to estimate correctly the philosophical value of his conclusions. Some typical passages should make this point clear.

> Standing on our microscopic fragment of a grain of sand [i.e. the earth], we [i.e. human beings] attempt to discover the nature and purpose of the universe which surrounds our home in space and time. Our first impression is something akin to terror. We find the universe terrifying because of its vast meaningless distances, terrifying because of its inconceivably long vistas of time which dwarf human history to the twinkling of an eye, terrifying because of our extreme loneliness, and because of the material insignificance of our home in space—a millionth part of a grain of sand out of all the sea-sand in the world. But above all else, we find the universe terrifying because it appears to be indifferent to life like our own ; emotion, ambition and achievement, art and religion all seem equally foreign to its plan. Perhaps we ought to say it appears to be actively hostile to life like our own (p. 3).

The next paragraph continues :

> Into such a universe we have stumbled, if not exactly by mistake, at least as the result of what may properly be described as an accident.

The use of such a word need not imply any surprise that our earth exists, for accidents will happen, and if the universe goes on for long enough, every conceivable accident is likely to happen in time (p. 4).

A little further on, having suggested that ' life may be merely an accidental consequence of the special set of laws by which the present universe is governed ', Jeans continues :

Again the word " accidental " may be challenged. For what if the creator of the universe selected one special set of laws just because they led to the appearance of life ? What if this were his way of creating life ? So long as we think of the creator as a magnified man-like being, activated by feelings and interests like our own, the challenge cannot be met, except perhaps by the remark that, when such a creator has once been postulated, no argument can add much to what has already been assumed. If, however, we dismiss every trace of anthropomorphism from our minds, there remains no reason for supposing that the present laws were specially selected in order to produce life. They are just as likely, for instance, to have been selected in order to produce magnetism or radio-activity—indeed more likely, since to all appearances physics plays an incomparably greater part in the universe than biology. *Viewed from a strictly material standpoint, the utter insignificance of life would seem to go far towards dispelling any idea that it forms a special interest of the Great Architect of the Universe* (p. 10. Italics mine).

A study of these passages (and of others like them which abound in his writings) is enlightening both with regard to Jeans's method of presenting his views and with regard to the reasons that have led him to adopt his philosophical conclusions. The reader can hardly fail to notice the emotional tone of the language used by Jeans, his sense of values, which is surely strangely perverted, and his confused, contradictory reasoning. Many devices are used apparently for no other purpose than to reduce the reader to a state of abject terror. In accordance with the temper of an age in which men admire size and material power, Jeans insists upon the magnitude of astronomical distances, upon the smallness of the earth, and upon the shortness of the span

of human history. In his purely expository writings Jeans has made brilliant use of comparative estimates of size and of distance in order to elucidate astronomical facts. Now, however, the comparison is dwelt upon simply in order to make the reader feel his own feebleness and insignificance in the material universe. It is no doubt for the sake of intensifying this feeling that the vast distances with which the astronomer deals are said to be ' meaningless '. Few readers are likely to pause to ask themselves whether a *small distance* would be *meaningful*. It is impossible to tell what answer Jeans would give, were he to be asked this question. Nowhere has he suggested a criterion for determining ' meaning ' in relation to distances. Is it not absurd to suppose that a *distance* could be ' meaningless ' or ' meaningful ' ? Certainly it would be interesting to learn how Jeans has discovered that stellar distances are ' meaningless ' and that stars are ' lonely '. There is an extraordinary, but by no means uncommon, confusion in the picture of human beings standing on a microscopic fragment of sand whilst they attempt to discover the nature of the universe. There is an incongruity here, for we do not dissociate the human thinker from the normal size of man, i.e. the size stated in terms of measures and measuring rods invented and used by men. Nor does Jeans intend us to forget these measures. On the contrary, the pathos of the picture depends upon there being vaguely present to the reader's mind the notion of a man clinging to too small a spar in a pathless ocean. If the earth is to be compared in size to a grain of sand, the human being must be correspondingly reduced in size.[1]

[1] When, in *The Universe Around Us*, Jeans was trying to explain in simple language, the methods and results of modern astronomical research, he made this reduction to scale in the case of the past age and probable future duration of the earth and of the life of man.

Such a picture, drawn to scale, would not, however, suit the purpose of the passage. The value which Jeans so evidently attaches to greatness in size is used both to reduce the reader to a humble frame of mind and to terrify him. In my opinion such a sense of values is perverted.[1] The awe which Kant felt when he contemplated 'the starry heavens above' is strikingly different. Such awe is due to an immediate awareness of the beauty of the night and is wholly independent of any knowledge of stellar magnitudes. Such awe may well have been felt by the Babylonian shepherds of old; it may be felt by an ignorant shepherd to-day. To be capable of such admiring contemplation; to be moved by pity and love; to have knowledge of the constitution of the stars might well seem more valuable than to be very big. Evidently Jeans thinks otherwise. He is content to deduce the insignificance of human beings from the smallness of the earth in comparison with the stars.

Jeans uses another means of terrifying the reader. This is the suggestion contained in the falsely emotional phrase 'into such a universe we have stumbled'. The notion inevitably suggested by this language is of fully developed human beings coming unawares into a world that is alien

[1] Cf. F. P. Ramsey: *Foundations of Mathematics*, p. 291. 'Where I seem to differ from some of my friends is in attaching little importance to physical size. I don't feel in the least humble before the vastness of the heavens. The stars may be large, but they cannot think or love; and these are qualities which impress me far more than size does. I take no credit for weighing nearly seventeen stone.

My picture of the world is drawn in perspective, and not like a model to scale. The foreground is occupied by human beings and the stars are all as small as threepenny bits.'

Eddington, however, seems to share Jeans's attitude: 'The contemplation of the galaxy impresses us with the insignificance of our own little world, but we have to go still lower in the valley of humiliation (*N.Ph.W.* 165).

to the environment from which they have sprung. But Jeans knows quite well that the suggestion is absurd. Its purpose is to create in his readers' minds the picture of a universe either indifferent to them or actively hostile. Between these alternatives Jeans wavers; either affords scope for his curiously emotional appeal to the interest of the common reader. Yet the success of this appeal depends upon an almost incredible degree of confusion. In the passage quoted on page 9, Jean speaks of 'the universe' as being 'indifferent' or 'actively hostile to life like our own'. But *indifference* or *hostility* can be significantly predicated only of living beings. In the last of the three passages quoted (page 10), Jeans seems to be recognizing the danger of thinking of the creator 'as a magnified man-like being, activated by feelings and interests like our own'. It is, however, important to notice the context in which this statement occurs. Jeans is considering a possible objection to the suggestion that the appearance of life in the universe may be 'accidental', the objection being that the creator may have selected just those laws that lead to life. He replies that, were the creator a magnified human being, then it would be reasonable to suppose that he would design to bring about the appearance of human beings. He rightly insists that such a postulate would have little worth. At this point he advises us to 'dismiss every trace of anthropomorphism from our minds', and argues that it is more likely that 'the present laws of the universe' have been 'selected' in order to produce magnetism rather than in order to produce life. He can then state his main conclusion, namely, that *from the material standpoint* there is no reason for supposing that the great Architect of the Universe has any special interest in life.

To regard the laws of the universe as having been specially

selected, to speak of laws as *producing* this, that, or the other is, then, not considered by Jeans to be inconsistent with dismissing 'every trace of anthropomorphism from our minds'. Indeed, the Great Architect of the Universe turns up in the last line of the paragraph that contains this exhortation. Yet, surely, the selecting of one among possible alternatives is a specifically human activity? The whole of Jeans's discussion is permeated by the notion of a Power which selects and rejects, plans and designs, seeks and achieves, thinks as human beings think although much more effectively and on a grander scale. The point of the pretended dismissal of anthropomorphism is to be found in the sentence I have italicized in the passage quoted on page 10. Our attention is being called to what will happen to our aspirations if we insist upon regarding the universe from a strictly material standpoint. As we shall see in the next chapter, the outcome of Jeans's meditations is a belief that the Great Architect is a pure Mathematician, and that the universe is his thoughts. Hence, there is no *matter* to be afraid of, and no meaningless distances to appal us. This last statement may strike the reader of this book as intended for a joke on my part. On the contrary, it is a summary statement of Jeans's own conclusion. The quotation of one passage must suffice:

> 'It is probably unnecessary to add that, on this view of things, the apparent vastness and emptiness of the universe, and our own insignificant size therein, need cause us neither bewilderment nor concern. We are not terrified by the size of the structures which our own thoughts create, nor by those which others imagine and describe to us. . . . The immensity of the Universe becomes a matter of satisfaction rather than awe; we are citizens of no mean city' (p. 143).

Thus Jeans concludes that 'the vastness and emptiness of the universe' is only apparent; yet 'the immensity of

the Universe' is a source of satisfaction to its citizens. . . . Perhaps Jeans is thinking of the pride of citizens of an Empire upon which the sun never sets, who murmur

> 'Wider still and wider, shall thy bounds be set,
> God who made thee mighty, make thee mightier yet'.

Possibly the obvious contradiction in the above statements is to be avoided by the change from a small to a capital U. However that may be, the anthropomorphic fallacy is very obvious in the conclusion that the Great Architect is a super-mathematician, in short, a Being well fitted to become President of the Royal Society—a colleague of Jeans himself. Yet there are times when Jeans seems to be seriously aware of the dangers of anthropomorphic theories. In the *New Background of Science* he pointed out the mistakes of the ancient Greeks in attributing natural occurrences to the agency of gods, and he wisely added, 'Such views of nature were unreflective and almost instinctive, arising in part from man's projecting his own personality on to nature, with a resultant confusion between man and nature, and in part from a mere fixation of infantile ideas' (p. 34). Can Jeans suppose that such projection of his own personality is scientifically permissible so long as it is reflective and based upon elaborate arguments? With the worth of these arguments we shall be concerned in the next chapter. Here it is important to stress how fundamental to Jeans's arguments the anthropomorphic fallacy is.

Unfortunately, Eddington is not entirely free from this vice. He indulges in a specious personification of Nature, ascribing to 'her' emotions, designs, frustrations, and successes. In *Science and the Unseen World* he says:

> 'Looking back over the geological record it would seem that Nature made nearly every possible mistake before she reached her

greatest achievement Man—or perhaps some would say her worst mistake of all. At one time she put her trust in armaments and gigantic size. Frozen in the rock is the evidence of her failures to provide a form fitted to endure and dominate—failures which we are only too ready to imitate. At last she tried a being of no great size, almost defenceless, defective in at least one of the most important sense-organs, one gift she bestowed to save him from threatened extinction—a certain stirring, a restlessness, in the organ called the brain. And so we come to Man' (p. 15).

This is not meant to be merely picturesque, for Eddington at once continues, 'It is with some such thoughts as these of the relation of Man to the visible universe that *the scientifically minded* [1] among us approach the problem of his relation to the Unseen World.' It is to be hoped that Eddington is mistaken concerning the thoughts of at least many of 'the scientifically minded', but there can be no doubt that he is accurately stating his own attitude. He does seem to believe in a strange anthropomorphic female, Nature, whose relation to God, or to the Universal Mind, he never seems squarely to face. His mode of approach, born of emotion finding its outlet in vague metaphorical expressions, is surely not characteristic of the scientifically minded. As we shall see later,[2] it obscures his discussion of 'Indeterminacy and the Quantum Theory', as the following quotation may suggest: 'The future is not predetermined, and Nature has no need to protect herself from giving away plans which she has not yet made' (*N.P.Sc.* 102). His habit of personifying does not stop with Nature. In an attempt to show that the directed radius is constant, there occurs this remarkable passage:

'The long and the short of it is that when the standard metre takes up a new position or direction it measures itself against the directed

[1] Italics mine.

[2] See below, p. 204 seq.

radius of the world in that region and direction, and takes up an extension which is a definite fraction of the directed radius. I do not see what else it could do. We picture the rod a little bewildered in its new surroundings wondering how large it ought to be—how much of the unfamiliar territory its boundaries ought to take in. It wants to do just what it did before. Recollections of the chunk of space it formerly filled do not help, because there is nothing of the nature of a landmark. The one thing it can recognize is a directed length belonging to the region where it finds itself; so it makes itself the same fraction of this directed length as it did before' (*N.Ph.W.* 143).

It is difficult to know whether Eddington is merely intending to entertain the reader by a little playful talk, or whether he has deluded himself into supposing that this sort of talk will enable the layman to understand what is meant by saying that 'the length of a specified material structure bears a constant ratio to the radius of curvature of the world at the place and in the direction in which it lies'—as he puts it in the *Mathematical Theory of Relativity*.[1] It is probably not possible to explain the point clearly to the non-scientific reader. Eddington can hardly be blamed for our deficiencies. But we might have expected that he would, at this point, have made some attempt to discuss the theory of measurement, and would have spared us the foolish picture of the 'bewildered little rod' which 'wonders how large it ought to be' and 'wants to do just what it did before'. At this stage of his discussion it was extremely important that Eddington should have striven to say as clearly as possible exactly what he meant, for from the above statement he derives the conclusion: 'The whole thing is a vicious circle. The law of gravitation is—a put-up job.'[2] This

[1] Op. cit., § 66.

[2] For a discussion of this contention, see below, p. 70 seq.

conclusion plays a considerable part in Eddington's final philosophical construction.

It may be thought that I am treading too heavily and showing myself insensitive to Eddington's joke. Some people may feel that there is no harm in this mode of writing, and that it is merely a picturesque way of enlivening lectures addressed to a mainly non-scientific group of people. It does not seem to me that this defence can be substantiated. The fundamental objection to the modes of expression so dear to both Eddington and Jeans is not merely that they are unilluminating ; it is that such writing obfuscates the common reader whilst pretending to enlighten him. These writers encourage the reader to believe that he has understood a theory when he has only been entertained by an irrelevant illustration. They persuade him to accept the philosophical theory that is put forward because it has been preceded by a good deal of difficult and abstruse physics which the reader is prepared to accept as correct since it has been presented by a competent scientist who has, moreover, the air of explaining the inexplicable. It seems almost as though Jeans was projecting into Nature the characteristics of his own and Eddington's popular writings when he said ' Heisenberg now makes it appear that Nature abhors accuracy and precision above all things.'

Chapter II

THE ESCAPE OF SIR JAMES JEANS

'Everyone is as God made him, and very often worse.'
CERVANTES

By means of the unsatisfactory devices discussed in the preceding chapter the mind of the common reader is prepared to accept certain pleasant conclusions. He is to be persuaded that there is a God who has created the world, who has designed man as the crown of this creation, and who will thus not leave him uncomforted; that Reality is spiritual; finally, that human beings can determine their own destiny.

Surprisingly little attention has been paid to the significance of the fact that these stupendous conclusions are supposed to be established by means of speculations based upon recent developments in the physical sciences. For more than a century we have been used to the dogmatism of physicists and biologists; we have allowed them to decide whether, and if so, to what extent, there is an opposition between science and religion, whether the 'facts' established by the former are irreconcilable with the 'dogmas' of the latter. We have allowed the scientists to claim the right of determining which, in this conflict, is victor. If, therefore, an eminent scientist (or a symposium of them) now proclaims that there is no conflict, or that at least there will soon be no conflict, or

that anyhow the conflict is lessening, the pronouncement is likely to be accepted with relief and in due humility. This has recently been happening. Everyone who is interested in contemporary discussions of the philosophical implications of the physical sciences has, of course, noted that the stupendous conclusions referred to above have been asserted by professional scientists. What is surprising, however, is that these conclusions appear in the course of arguments *from* physical theories. Thus Jeans definitely offers us an argument for the existence of God and for the spiritual nature of the universe drawn from the present stage of physics. Eddington confines himself to the statement, 'The idea of a Universal Mind or Logos would be, I think, a fairly plausible inference from the present state of scientific theory; at least it is in harmony with it' (*N.Ph.W.* 338). He immediately adds, 'But if so, all that our inquiry justifies us in asserting is a purely colourless pantheism. Science cannot tell whether the world-spirit is good or evil, and its halting argument for the existence of a God might equally well be turned into an argument for the existence of a Devil.' This cautious reservation is of great importance, and will be discussed in a later chapter.[1] The point to notice at the moment is that Eddington does hold that science gives us an *argument*, albeit a halting one, for the existence of a Universal Mind.

It would, then, seem that these scientists hold that it lies within the competence of physics to establish that there is a God, or at least to produce a plausible argument for a Universal Mind. Surely this is very odd. The physicist, in so far as he is concerned with physical science,[2] cannot

[1] See below, p. 258.

[2] This qualification is required because the physicist is a man having interests beyond physics; he is entitled to instruct the layman on

establish that there is a God—or a Devil—unless He is an entity of the kind studied by the physicist as such. If He is an entity of such a kind, then there is *no reason at all* to suppose that He is God the Comforter, and many reasons for supposing that He is not. If He is not an entity of such a kind, then *no* changes in physical theories can provide any reasons at all for saying anything about Him. Hence, it seems to me, both Jeans and Eddington are on the wrong tack. There is, however, an important difference between Jeans's mode of treating the argument and that of Eddington. To Jeans the argument offers itself as an escape from the fear that man is an insignificant item in the universe. Eddington has no such fear ; for him the argument for a Universal Mind is inextricably bound up with his conception of the nature of the physical world that includes stars, human brains, and tables. But he does not desire to base any religious belief upon scientific discoveries. This difference between the two scientists is responsible for the greater subtlety of Eddington's argument and for its wider ramifications. It justifies a difference in the criticism of their arguments. I shall discuss Eddington's theories in considerable detail ; what I have to say about Jeans will be mainly contained in the present chapter.

I have already pointed out that Jeans insists upon the necessity of avoiding anthropomorphism. He rightly recognizes the danger of drawing conclusions from the use

matters appertaining to physical science, but when he goes beyond its domain his arguments are not immune to criticism by the layman. The statement in the text is not intended to deny that the physicist may be in a peculiarly advantageous position for advancing reasons for a belief in the existence of God ; it is intended only to emphasize that, if the physicist does attempt to bring forward such reasons, he is no longer speaking merely as a physicist. This Eddington admits. See below, p. 120.

of concepts based upon human behaviour—a danger from which Newton's statement of the laws of motion is not exempt. It is indeed odd that Jeans should so clearly see the absurdity of the anthropomorphic fallacy, and yet not himself be able to avoid falling into it. In his book, *The New Background of Science*, having pointed out that recent developments in science have led to the abandonment of the mechanical view of the universe, he adds :

> The mechanical universe in which objects push one another about like players in a football scrimmage has proved to be as illusory as the earlier animistic universe in which gods and goddesses pushed objects about to gratify their own caprices and whims. We are beginning to see that man had freed himself from the anthropomorphic error of imagining that the workings of nature could be compared to those of his own whims and caprices, only to fall headlong into the second anthropomorphic error of imagining that they could be compared to the workings of his own muscles and sinews. Nature no more models her behaviour on the muscles and sinews of our bodies than on the desires and caprices of our minds (p. 43).

But Jeans cannot free himself from the belief that Nature *models herself* on something. ' She does not,' he says, ' model her behaviour, so to speak, on that forced on us by our whims and passions, or on that of our muscles and joints, but on that of our thinking minds. This remains true whether our minds impress their laws upon nature,[1] or she impresses her laws on us, and provides a sufficient justification for thinking of the designer of the universe as a mathematician.' [2]

In the course of Jeans's argument there is a transition, never explicitly noted, from this goddess Nature to God the

[1] As Eddington thinks. See below, p. 91.

[2] *The Mysterious Universe*, p. 135. Subsequent quotations from Jeans, in this chapter, are from the same book, unless otherwise stated.

creator. The conclusion which Jeans draws from the 'ascertained facts and provisional hypotheses' of astronomy and physics is based upon the assumption that the universe has been designed by a creator. Perhaps Jeans does not regard this as an assumption but rather as an inference from scientific facts. It is difficult to be sure. 'We discover', he says, 'that the universe shows evidence of a designing or controlling power that has something in common with our own individual minds—not, so far as we have discovered, emotion, morality, or aesthetic appreciation, but the tendency to think in the way which, for want of a better word, we describe as mathematical. And while much of it may be hostile to the appendages of life, much also is akin to the fundamental activities of life; we are not so much strangers or intruders in the universe as we at first thought' (p. 149). It is in this way that Sir James begins to make his escape from the thought of 'a universe which was clearly not designed for life, and which, to all appearances, is either totally indifferent or definitely hostile to it' (p. 13).

Two main lines of reflection seem to be responsible for Jeans's method of escape. The first is his anthropomorphic belief that the universe has been consciously designed; the second is due to the all-important part played by mathematics in modern physics. Nothing in the form of an argument seems to be offered in favour of the view that the universe must have been created; it seems possible that Jeans believes that such an argument could be based upon the fact of entropy,[1] but he does not clearly say so. Possibly the following statement is considered as an argument: 'As we trace the stream of time backwards, we encounter many indications that, after a long enough journey,

[1] Such an argument will be considered in detail in connexion with Eddington. See below, p. 258.

we must come to its source, a time before which the present universe does not exist. Nature frowns upon perpetual motion machines and it is *a priori* very unlikely that her universe will provide an example, on the grand scale, of the mechanism she abhors' (p. 144). It is difficult to determine whether Jeans is using 'Nature' and 'her universe' as synonymous with 'God' and 'His creation'. If so, then the first stage in his argument is based upon considerations connected with the second law of thermodynamics; if not, then Jeans is simply assuming that there must have been a creator. Having assumed a Creator, his second line of reflection leads him to the Great Mathematician. Modern physicists have abandoned the attempt to find a working model to represent the physical interpretation of the mathematical formulae. Thus Jeans stresses the fact that '*all* the pictures which science now draws of nature, and which alone seem capable of according with observational fact, are *mathematical* pictures' (p. 127). Thus Jeans is led to the conclusion that 'from the intrinsic evidence of his creation, the Great Architect of the Universe now begins to appear as a pure mathematician' (p. 134). Jeans then concludes that 'the universe can be best pictured, although still very imperfectly and inadequately, as consisting in pure thought, the thought of what, for want of a wider word, we must describe as a mathematical thinker' (p. 136).

It is not easy to determine whether Jeans regards the statement that the universe has been *designed* by a pure mathematician to be equivalent to the statement that it consists of the *thoughts* of a pure mathematician. These two statements are certainly very different but Jeans does not seem to be aware of the difference. Whether he does distinguish between them or not is, however, a question

of little importance compared with the problem of determining what possible meaning can be attached to either statement. It is not 'the want of a better word' than "mathematical", or 'the want of a wider word' than "a mathematical thinker", that renders these sentences hopelessly obscure and probably nonsensical. What is lacking is any clear indication of what Jeans understands by "thought" and by "thinking". Yet it is upon the concept of *thought* that the whole of his metaphysics depends. Had he been a philosopher either by training or by inclination he would surely have realized the necessity of attempting to analyse a concept so fundamental for his argument.

So far as he offers any argument in favour of the view that the universe is created by a mathematician and consists in the thoughts of this super-mathematician, the argument appears to take the following form. All physical happenings have a mathematical aspect, or, as Jeans also puts it, can be mathematically described. Modern physics is becoming increasingly mathematical; *physical* discoveries can be made *by the use of mathematics alone.* Thus not only do physical entities show themselves amenable to mathematical treatment but, further, discoveries concerning their behaviour may be made by the mathematician. This is not the form in which Jeans himself states his argument, but I think it presents his view fairly and without the encumbrance of his metaphorical language. He then argues that 'the final truth about a phenomenon resides in the mathematical description of it; so long as there is no imperfection in this our knowledge of the phenomenon is complete. We go beyond the mathematical formula at our own risk; we may find a model or picture which helps us to understand it, but we have no right to expect this, and our failure

to find such a model or picture need not indicate that either our reasoning or our knowledge is at fault. The making of models or pictures to explain mathematical formulae and the phenomena they describe, is not a step towards, but a step away from reality; it is like making graven images of a spirit' (*M.U.* 141).

This argument is sufficiently curious; it shows that Jeans has been guilty of two odd blunders. First, he seems to have forgotten that, given a certain amount of multiplicity, any collection of things, and thus any world, could be brought within the scope of mathematical formulae. Secondly, he has confused pure mathematics with applied mathematics. His first blunder has prevented him from seeing that what is surprising is not that the world 'obeys mathematical laws' but that terrestrial mathematicians should be competent to discover them.[1] His second blunder leads him to impute to God the desire to make models of his mathematical creations, in fact to make 'graven images'. Pure mathematics is concerned with symbols and with showing how different sets of symbols are equivalent, i.e. are mutually deducible. The pure mathematician is not at all concerned with the physical interpretation of his symbolic expressions. His procedure is as reasonable when there is *no* physical interpretation as when there is such an interpretation; his enjoyment of his work in mathematics is equally independent of its physical application. The physicist, on the contrary, is interested mainly in the interpretation, i.e. in the experimental verification of the mathematical formulae provided by the pure mathematician.[2]

[1] Cf. Bertrand Russell: *The Analysis of Matter*, p. 232.

[2] Clerk Maxwell's discovery that light is an electromagnetic phenomenon provides a good illustration of this point. He expressed in a series of equations the known phenomena of electricity and

Only part of what the mathematician provides is of use to the physicist; some mathematical expressions have no physical interpretation. The use made by the physicist of the mathematical expressions leads him to make assertions which are different in kind from the assertions made by the pure mathematician. The physicist's assertions are always to be tested by reference to sensible experience; he begins from and returns to sensible experience. In other words, physics is an empirical science. Such reference to sense-experience is, however, totally irrelevant to the interests of the pure mathematician. Jeans's God, it seems, is somewhat of a tyro in mathematics, taking delight in constructing solids and making elaborate mathematical models.

Jeans makes no effort to explain how it is that the Great Mathematician should have turned aside from his mathematical activities and condescended to create the world. Perhaps he has been unable to see the importance of this question because he has confused *thinking* with *thoughts*. Thus speaking of the 'terrestrial pure mathematician' Jeans says that he 'does not concern himself with material substance, but with pure thought. His creations are not only created by thought but consist of thought, just as the creations of

magnetism and of their interactions as discovered by Faraday. In this way he obtained a differential equation which corresponded in form exactly with the equation for waves. From this correspondence Maxwell deduced that electromagnetic experiments would give rise to waves which would travel with a speed calculable in terms of electric and magnetic constants of the aether. He discovered that the velocity of the waves would be that of the velocity of light. Thus, by means of manipulative mathematical symbols, Clerk Maxwell made an important physical discovery. But that it was a physical discovery was shown only by the fact that the symbols admitted of a physical interpretation subsequently verified by experimental observation.

the engineer consist of engines'. This is an extraordinarily muddled statement. The engineer may be said to create *engines*; he does not create *engineers*, nor *the thinking* of engineers. Granted that the engineer is thinking creatively when he is designing an engine, the engine that is made is not itself *the thinking* of the engineer nor a *thought* in his mind. It is impossible to attach any meaning to Jeans's use of the words "just as" in the statement quoted above. It reveals, however, Jeans's failure to distinguish between saying that the universe is created by God's thinking and saying that it is God's thought.

In view of these muddles it is hardly surprising that Jeans has not made any attempt to show how 'our whims and passions' are to be included in his scheme, and thus to be regarded as thoughts in God's mind. It may seem unreasonable to demand that account should be taken of everything. It must, however, be remembered that Jeans has insisted that *the universe* is God's pure thought. Yet he has also admitted (in a passage already quoted) that the controlling mind has 'in common with our own individual minds' only the tendency to think mathematically; emotion, morality, and aesthetic appreciation are excluded. Given this exclusion, then the sounds of a Beethoven sonata could be replaced by a series of curves or a set of mathematical formulae. By studying these formulae we might discover that Beethoven was a mathematician. We should not be able to discover that he was a musician because we have *replaced* the sounds by the mathematical expressions by means of which they could be *mathematically*, but not musically, described. To discover the musician we need further what Jeans would no doubt call *musical concepts*. But it then becomes impossible to maintain that the universe is God's mathematical thoughts or God thinking mathematically.

Perhaps the source of the confusions into which Jeans falls lies in the fact that he believes both that a mathematical description of a phenomenon can give *complete* knowledge of the phenomenon and also that the phenomenon is indeed an appearance of an unknowable reality. It is of no small significance that he has prefixed to *The Mysterious Universe* Plato's famous simile of the cave. His fear that man is imprisoned in an alien universe leads him easily to take the view that what we know is always appearance, never reality. He regards 'the outstanding achievement of twentieth-century physics' as consisting in 'the general recognition that we are not yet in contact with ultimate reality'. He insists that 'we are still imprisoned in our cave, with our backs to the light, and can only watch the shadows on the wall' (p. 127). Fortunately, our minds have created mathematics, and we find that the shadows on the wall of the cave obey our mathematical rules. In a remarkable passage Jeans says: 'To drop our metaphor, Nature seems very conversant with the rules of pure mathematics, as our mathematicians have formulated them in their studies, out of their own inner consciousness and without drawing to any appreciable extent on their experience of the outer world' (p. 130). It is not quite clear *how much* of the metaphor of the cave —and the cave-men playing shadow games of chess—has been dropped in this statement; at the least, however, it is clear that Jeans supposes that mathematicians have created mathematics and that mathematicians have also experience of an *outer* world. But it is extraordinarily difficult to discover what is meant by this 'outer world' and what exactly Jeans conceives to be the nature of mathematics.

This difficulty is increased when we proceed to consider Jeans's latest pronouncement on this topic—his presidential Address to the British Association in 1934. Its title is 'The

New World-Picture of Modern Physics ' ; its burden is that there is no World-Picture.[1]

Jeans has now decided that mathematics is the creation of the celestial Mathematician. ' It was, I think,' he remarks, ' Krönecker who said that in arithmetic God made the integers and man made the rest ; in the same spirit we may add that in physics God made the mathematics and man made the rest ' (p. 356). This division of labour will need to be examined. First, however, it is worth while to consider the final stage of Jeans's escape as set forth in *The Mysterious Universe*. He argues that when the cave-men happily discovered that the shadows thrown on their prison walls obeyed the rules formulated by themselves ' out of their own inner consciousness ', they drew the conclusion that the same rules must have been formulated by the creator of that which threw the shadows, i.e. by a celestial Mathematician. Accordingly, ' we need find no mystery in the nature of the rolling contact of our consciousness with the empty soap-bubble we call space-time, for it reduces merely to a contact between mind and a creation of mind—like the reading of a book or the listening to music ' (p. 143). The universe is then mathematical ; mathematics is a creation of mind ; a creation of mind is thought ; consequently, the universe is ' a world of pure thought '. It is in this way that Jeans reaches his final escape—' Mind no longer appears as an accidental intruder into the realm of matter ; we are beginning to suspect that we ought rather to hail it as the creator and governor of the realm of matter—not of

[1] This Address was fully reported in *The Times* of 6 Sept. that year. It was reprinted in the British Association number of *Nature*, 8 Sept., 1934. I wrote an article about it, entitled ' The Parables of Sir James Jeans ', in the journal, *Adult Education*, Dec. 1934. Some part of the following discussion is taken from that article.

course our individual minds, but the mind in which the individual atoms out of which our individual minds have grown exist as thoughts' (p. 148).

This conclusion has, as Jeans points out, much in common with the position of Berkeley. There is more of Malebranche in it, however, than Berkeley would have relished. The objectivity of things 'arises from their subsisting "in the mind of some eternal spirit"' (p. 137). Substantiality, he says, 'is a purely mental concept measuring the direct effect of objects on our sense of touch' (p. 138). There are three grades of substantiality: the thoughts of God; the thoughts of men when they are awake; the thoughts of men when they dream. The second grade includes the things of everyday life; these are, however, somehow also included in the first grade for 'the space of everyday life' and 'the time of waking life, which flows at the same even rate for us all', are the space and time of the universal mind. The laws of nature, i.e. 'the laws to which phenomena conform in our waking hours', are 'the laws of thought of a universal mind' (p. 140). Oddly enough Jeans maintains that 'the uniformity of nature proclaims the self-consistency of this mind', so that the universal mind, unlike Nature, does not 'abhor accuracy and precision'.

It would seem, then, that the entities with which physics is concerned are not, after all, to be considered as shadows of God's thoughts; they are themselves God's thoughts, and the physicist is 'a cell' in the brain, or mind, of God. But Jeans is unwilling to regard this conclusion as leading to idealism, for he holds that 'the real essence of substances' still evades us. We may say that 'objective realities exist' on the ground that 'certain things affect your consciousness and mine in the same way' (p. 137). But we go too far, he thinks, if we label these 'things' as 'real' or 'ideal';

the proper label is ' mathematical '—provided that " mathematical " is used ' to connote the whole of pure thought '. The point he is anxious to insist upon is that the label " mathematical " ' does not imply anything as to what things are in their ultimate essence, but merely something as to how they behave ' (p. 138).

Jeans's presidential Address shows how deeply rooted is his belief that there is a ' mysterious world outside ourselves to which our minds can never penetrate '.[1] It is odd to find that Jeans places in this mysterious impenetrable world ' the essential nature of a centimetre ', as well as a wave-length and that which ' sends messages through our senses '. We must remember, however, his division of labour, assigning to God the making of mathematics and to man that ' in physics ' which is not mathematics. When he attempts to discover what this is his answer is determined by a fundamental dictum, clearly stated here and certainly assumed in his other writings. This dictum is: ' Our minds can only be acquainted with things inside themselves—never with things outside.' [2] This dictum is far from clear since Jeans does not anywhere indicate how we are to understand the opposition of ' inside our minds ' and ' outside our minds ' ; it is not even clear whether he takes the opposition as equivalent to the distinction between ' subjective ' and ' objective '. Yet these distinctions play an important part in his discussion. The fundamental dictum leads him to the conclusion that ' the external world is essentially of the same nature as mental ideas ', presumably on the ground that we ' know ' the external world and we *can* know only that which is inside our minds. As he naïvely remarks, ' It may seem

[1] This and the following quotations (unless otherwise stated) are taken from the Presidential Address.

[2] See below, p. 104.

strange, and almost too good to be true, that Nature should in the last resort consist of something we can really understand.' "Nature" and "the external world" are, then, used as synonyms. The external world is not 'that mysterious world outside ourselves to which our minds can never penetrate', for the external world we can know and Nature we can 'understand'. It seems, then, that *objective* and *subjective* both fall within 'that which is inside our minds'. That this interpretation is correct is supported by the fact that Jeans maintains that the general thesis of the new physics is 'that the Nature we study does not consist so much of something we perceive as of our perceptions; it is not the object of the subject-object relation but the relation itself. There is, in fact, no clear-cut division between the subject and object, they form an indivisible whole which now becomes Nature'. Thus Nature, it seems, consists of our *perceivings* and of *that which we perceive*, indissolubly bound together. What, then, do we perceive? The answer given to this question is extraordinarily obscure.

In order to determine what this answer is we have first to consider what Jeans regards as the most fundamental distinction between classical physics and 'the new physics'. He certainly wishes to stress that there has been a revolution—in fact, a cataclysmic upheaval. Speaking in the metaphorical language that is natural to him, Jeans asserts that the department of physics in 'the main edifice of science' looks like 'a building which has been brought down in ruins by a succession of earthquake shocks'. These earthquake shocks were facts of observation. The building fell 'because it was not built on the solid rock of ascertained fact but on the ever-shifting sands of conjecture and speculation'. These conjectures failed since they were based upon the assumption that the mind, 'which could never get

outside itself ', could nevertheless find familiar objects, such as billiard-balls, jellies and spinning-tops, in terms of which to ' explain what had existed from all eternity '. But Jeans insists, the truths of Nature ' can only be made comprehensible in the form of parables '. In his opinion ' the fundamental mistake of the old-fashioned physicist was that he failed to distinguish between the half-truths of parables and the literal truth '.

The reader of Jeans's Address might well expect at this point that Jeans would make clear the distinction between the ' half-truths of parables ' and ' the literal truth ', and would give some indication as to *what* is the literal truth. Unfortunately, he does not. On the one hand he insists that the physicist ' can never get beyond x, y, and z '. He argues that ' our picture of the universe—the synthesis of our knowledge—must necessarily be mathematical in form.' On the other hand, having pointed out that the modern physicist ' divides the concepts of physics into observables and unobservables ', he maintains that ' the observables embody facts of observation, and so are purely numerical or mathematical in their content; the unobservables are the pictorial details of the parables '. It is difficult to see how a fact of observation must be purely numerical in content; yet this must be the force of the ' and so ' in the statement just quoted. It is no less difficult to see how ' unobservables ' can constitute ' pictorial details '. The difficulty is increased when we are told that the unobservables—' the concrete details of the picture '—are ' the apples, the pears, the bananas, the aether, the atoms and electrons ' which are said to be ' mere clothing that we ourselves drape over our mathematical symbols '. These are said ' not to belong to Nature but to the parables by which we try to make Nature comprehensible '.

Surely there is a serious muddle here. Jeans has noticed an error made by the older physicists. They wanted *something* in which waves could travel; accordingly, they invented the aether. The aether is unobservable. It is well known that, as physics developed in the nineteenth century, the aether came to be endowed with incompatible attributes. It remained in the physicist's vocabulary merely —as Lord Salisbury said—to provide a substantive for the verb 'to undulate'. Jeans is not content to put the point so simply. It may not be nonsensical, although unhelpfully metaphorical, to say that the aether is 'clothing which we drape over our mathematical symbols'; it may be convenient to say that the notion of the aether is due to an attempt to provide a model for a mathematical description of physical phenomena. But Jeans puts the aether, together with electrons and waves, on the same level as apples, bananas, and—I suppose—tables. To say that '*apples* are mere clothing which we ourselves drape over our mathematical symbols' is to say something that has no sense; it is neither to talk in parables nor to speak the literal truth.[1] It may not be nonsensical to say that, in the description of light as of the nature of waves, only the word 'wave', in its strictly mathematical sense, can be said to be 'the content of ascertained fact', whereas 'all the rest is pictorial detail, introduced to help out the inherited limitations of our minds'. But it is impossible to attach meaning[2] to the further statement that the waves are 'waves of knowledge—or, perhaps even better still, waves of imperfections of knowledge—of the position of the electron'. The obscure is rendered even more

[1] I find a similar difficulty in Eddington's remark, 'To reach the reality of the table we need to be endowed with sense-organs to weave images and illusions about it' (*N.Ph.W.* 324).

[2] That is in the sense in which Jeans uses the phrase.

obscure when we read that ' Nature consists of waves and that these are of the general quality of waves of knowledge, or of absence of knowledge, in our own minds ', for we have already been told that Nature is ' our perceptions '. It would seem that on this view only a modern physicist has perceptions of the stars. It is incredible that Jeans should wish to maintain this, but it certainly follows from what he has said.

It is not improbable that Jeans is unable to make up his mind whether *Nature* is our knowledge or whether our *knowledge* is *of* Nature. In contrasting the ' particle-parable ' with the ' wave-parable ' (or ' picture '), he has insisted that observation constantly supports ' the wave-picture—not merely, be it noted, as a picture of our knowledge of Nature, but as a picture of Nature itself '. Here again his argument depends upon his fundamental dictum—that we can only be acquainted with what is inside our minds. Hence ' if ever we are to know the true nature of waves, these waves must consist of something we already have in our own minds '. What then, he appears to ask himself, can be in our own minds ? To which he answers : ' Now knowledge and absence of knowledge satisfy this criterion as few other things could ; waves in an aether, for example, emphatically did not.' Leaving aside the difficulty of making sense of the statement that absence of knowledge is in our minds, the question may be pressed why, if Nature *is* our knowledge, we need parables to make Nature comprehensible. It does not seem to make sense to speak of ' making ' *knowledge* comprehensible. Either what is known is comprehensible or there is not knowledge. It is good sense, however, to speak of making a *theory about* Nature comprehensible to those who have not followed the steps which necessitated the theory. If this were what Jeans wished to maintain

there would be some justification for speaking in parables, still more for using analogical illustrations. But this clearly is not what he is maintaining ; he is saying that Nature is itself knowledge. He remains troubled concerning what lies beyond Nature, and thus beyond knowledge.

There is something almost pathetic in Jeans's plaint that we can never know the essential nature of a centimetre. Presumably to know this would be to know something mathematical. Now, according to Jeans, God has made mathematics, and although we are thoughts in God's mind, we may not be able to know God's thoughts. But Jeans also maintains that our knowledge of a centimetre ' becomes real ' the moment we are told that a centimetre is, for instance, ' a certain multiple of the wave-length of a line in the cadmium-spectrum ', but ' at that same moment it [our knowledge] also becomes purely numerical—a knowledge of a value of a ratio '. The difficulty is to see why Jeans supposes that a centimetre is anything other than a numerical ratio. What, we are compelled to ask, is this ' thing outside ', which is ' the essential nature of a centimetre ' ? It is surely significant that Jeans reiterates this question in various forms. He cannot free himself from the belief that there is ' something outside ' which ' sends messages ' to us. At the same time he is anxious to insist that physics is not concerned with what lies outside. If he were saying only that physics is not concerned with what cannot be known, with what is in principle *unknowable*, then his statement would be indisputable. But it would also be irrelevant. Neither physics nor philosophy can be concerned with that which under no circumstances is knowable. Surely Jeans does not intend merely to assert this incontrovertible fact ; he must intend to say something more significant. The difficulty is to find out *what* this can be.

If we could discover this, we should understand what Jeans means by 'the outer world' to which our minds can never penetrate. The belief in this 'outer world' is, I think, the chief source of the amazing confusions with which this Address abounds. We receive knowledge of the outer world through messages 'passed on from our senses'. The messages come along 'the frameworks of space and time'. But space and time are not realities of Nature; they are 'mere mental frameworks of our own construction'. Nevertheless, 'space and time are of preponderating importance to our minds as the media through which the messages from the outer world enter "the gateways of knowledge", our senses, and in terms of which they are classified'. But 'what enters through the gateways of knowledge' is 'appearances rather than reality'. This statement seems curiously inconsistent with Jeans's metaphor that the physicist builds 'only on the solid rock, and with the solid bricks of ascertained fact', but possibly Jeans has slipped into a familiar pair of opposed words instead of using some word, such as 'aspect' which would have expressed his thought better. This is suggested by the fact that he immediately goes on to point out that the task of theoretical physics 'resembles that of the cartographer or map-maker rather than that of the geologist or mining engineer'. He makes excellent use of this illustration, but, unfortunately, plunges into obscurity again by using the too familiar illustration of a telephone exchange as an analogue of the way in which we receive messages from the outer world.

It is, I think, impossible to disentangle the confusions in Jeans's account in such a way as to obtain any clear conception of what his view is. He attempts to maintain each of the following six statements: (1) Space and time are mere

mental constructs ; (2) Space and time are the media through which our senses receive messages ; (3) These messages are from the outer world ; (4) These messages give us knowledge ; (5) Nature is our knowledge ; (6) What enters through the gateways of knowledge is appearance rather than reality. It is impossible to accept (1) together with (2) and (3). He leaves (4) and (5) completely unexplained, whilst, taken in conjunction with (6), they appear to be nonsensical. It may well be the case that space and time, *as required by physics*, are nothing but forms of order appropriate to the co-ordinating of our sensible observations. But if so, then they cannot also consistently be regarded as *media* through which ' our senses receive messages '. Jeans has fallen another victim to the plausible but fundamentally unclear analogy of the telephone exchange. He seems to be mentally in the position of a plain man who might suppose that the negative *word* " wireless ", instead of " radio ", signifies nothing but the absence of something.

The question of determinism will be dealt with in a later chapter, but certain points in Jeans's treatment of the problem in this Address require to be mentioned here. Jeans assigns different functions to the particle-picture and to the wave-picture. The former, he says, ' is a materialistic picture which caters for those who wish to see their universe mapped out as matter existing in space and time '. The latter is ' a determinist picture which caters for those who ask the question, " What is going to happen next ? " '. The particle-picture is indeterminist, but the wave-picture, ' which observation confirms in every known experiment, exhibits a complete determinism '. But the determinism ' is one of waves, and so, in the last resort, of knowledge. Where we are not ourselves concerned, we can only say that event follows event ; where we are concerned, only that know-

ledge follows knowledge. Even this knowledge is one only of probabilities and not of certainties ; it is at best a smeared picture of the clear-cut reality which we believe to be beneath '. Since, he argues, it is but a smeared picture, ' it is impossible to decide whether the determinism of the wave-picture originates in the underlying reality or not '. On the face of it, this is a cautious and reasonable statement, although it leaves obscure what is to be understood by ' the underlying reality ', which is said to be ' clear-cut '. It is more difficult to follow his statement of what he takes to be a fundamental difference between two ' determinisms ', namely the determinism of the old physics, and the determinism of the new physics. ' There is,' he says, ' all the difference in the world between the two determinisms. For in the old physics the perceiving mind was a spectator ; in the new it is an actor. Nature no longer forms a closed system detached from the perceiving mind ; the perceiver and perceived are interacting parts of a single system. The Nature depicted by the wave-picture in some way embraces our minds as well as inanimate matter. Things still change solely as they are compelled, but it no longer seems impossible that part of the compulsion may originate in our own minds.' It is unfortunate that no clue is provided as to what is meant by " things " in the last sentence. *What* is compelled to change, and *what* compels the change ? Jeans gives a partial answer only to the second question—namely, ' part of the compulsion may originate in our own minds '. This is extraordinarily obscure. To what extent is this statement to be regarded as in disagreement with the statement made in *The Mysterious Universe*, namely, ' the future may not be as unalterably determined by the past as we used to think ; in part at least it may rest on the knees of whatever Gods there be ' (p. 25). The Gods would now seem to be

our own minds. It is difficult to tell, for it is impossible to attach any clear meaning to either of these statements when we bear in mind that, according to Jeans, Nature is our knowledge. Yet he does mean this to be taken seriously. Thus, in discussing the behaviour of a shower of electrons shot against the barrier formed by an adverse electro-motive force, he says that this behaviour 'appears to be in flat contradiction to the law of conservation of energy'. He then adds the odd statement: 'we must remember that waves of knowledge are not likely to own allegiance to this law'. This statement is odd, not because of any question of likelihood or unlikelihood, but because to speak of knowledge, even *waves* of knowledge, as 'owning' or 'not owning allegiance' to a law is to say something that is without sense.

If Jeans is troubled by objections based upon the maintenance of the law of conservation of energy, one would expect him to have taken a different method of escape from the objection. It might be supposed that a modern scientist would have insisted that the law of conservation of energy is not, in fact, a law, nor even a principle, but a *convention*. This way of escape is unfortunately barred to Jeans owing to his failure to consider *what* in physics is *convention*, what is *knowledge*, and what there is *of which* we can be said to have knowledge. He is in too great a hurry to pass to the conclusion that the new physics has 'proved' that the 'objective and material universe' of the nineteenth-century scientist consists of 'little more than constructs of our own minds'. 'To this extent,' he urges, 'modern physics has moved in the direction of philosophic idealism.'

I am not here concerned to deny 'philosophic idealism', still less to disagree with Jeans's statement that 'both materialism and matter need to be redefined in the light of our

new knowledge'. On the contrary, I should wish to urge that both idealism and materialism, as understood by Jeans, are out of date. The point of the foregoing criticisms is that these cloudy speculations of Sir James Jeans cannot properly be regarded as affording the common reader any clear information as to the 'philosophical implications' of the new physics.

Part II

THE PHYSICIST AND THE WORLD

'That men should rush with violence from one extreme, without going more or less into the contrary extreme, is not to be expected from the weakness of human nature. Des Cartes and his followers were not exempt from this weakness; they thought that extension, figure, and motion, were sufficient to resolve all the phaenomena of the material system. To admit other qualities whose cause is unknown, was to return to Egypt, from which they had been so happily delivered.'

THOMAS REID

Chapter III

'FURNITURE OF THE EARTH'

'Roused by the shock he started from his trance—
The cold white light of morning, the blue moon
Low in the west, the clear and garish hills,
The distant valley and the vacant woods,
Spread round him where he stood. Whither have fled
The hues of heaven that canopied his bower
Of yesternight? The sounds that soothed his sleep,
The mystery and the majesty of Earth,
The joy, the exultation?'

WORDSWORTH

I ENTER my study and see the blue curtains fluttering in the breeze, for the windows are open. I notice a bowl of roses on the table; it was not there when I went out. Clumsily I stumble against the table, bruising my leg against its hard edge; it is a heavy table and scarcely moves under the impact of my weight. I take a rose from the bowl, press it to my face, feel the softness of the petals, and smell its characteristic scent. I rejoice in the beauty of the graded shading of the crimson petals. In short—I am in a familiar room, seeing, touching, smelling familiar things, thinking familiar thoughts, experiencing familiar emotions.

In some such way might any common reader describe his experiences in the familiar world that he inhabits. With his eyes shut he may recognize a rose from its perfume, stumble against a solid obstacle and recognize it to be a

table, and feel the pain from its contact with his comparatively yielding flesh. You, who are reading this chapter, may pause and look around you. Perhaps you are in your study, perhaps seated on the seashore, or in a cornfield, or on board ship. Wherever you may be, you will see objects distinguishable one from another, differing in colour and in shape ; probably you are hearing various sounds. You can see the printed marks on this page, and notice that they are black marks on a whitish background. That you are perceiving something coloured and shaped you will not deny ; that your body presses against something solid you are convinced ; that, if you wish, you can stop reading this book, you know quite well. It may be assumed that you have some interest in philosophy ; otherwise you would not be reading *this*. Perhaps you have allowed yourself to be persuaded that the page is not ' really coloured ', that the seat upon which you are sitting is not ' really solid ' ; that you hear only ' illusory sounds '. If so, it is for such as you that this chapter is written.

Imagine the following scene. You are handed a dish containing some apples—rosy-cheeked, green apples. You take the one nearest to you, and realize that you have been ' had '. The ' apple ' is too hard and not heavy enough to be really an apple ; as you tap it with your finger-nail it gives out a sound such as never came from tapping a ' real ' apple. You admire the neatness of the imitation. To sight the illusion is perfect. It is quite sensible to contrast this ingenious fake with a ' real ' apple, for a ' real ' apple just is an object that *really* is an apple, and not only *seems* to be one. This fake is an object that looks to your eyes to be an apple, but neither feels nor tastes as an apple does. As soon as you pick it up you know that it is not an apple ; there is no need to taste it. We should be speaking in con-

formity with the rules of good English if we were to say that the dish contained real apples and imitation apples. But this mode of speaking does not lead us to suppose that there are two varieties of *apples*, namely real and imitation apples, as there are Bramley Seedlings and Blenheim pippins. Again, a shadow may be thrown on a wall, or an image may be thrown through a lantern on to a screen. We distinguish the shadow from the object of which it is the shadow, the image from that of which it is the image. Shadow and image are apprehensible only by sight; they really are visual, i.e. *seeable*, entities. I can see a man, and I can see his shadow; but there is not both a *real* man and a *shadow* man; there is just the shadow of the man.

This point may seem to have been unduly laboured. It is, however, of great importance. The words " real " and " really " are familiar words; they are variously used in every-day speech, and are not, as a rule, used ambiguously. The opposition between a *real* object and an *imitation* of a real object is clear. So, too, is the opposition between ' really seeing a man ' and having an illusion.[1] We can speak sensibly of the distinction between ' the real size ' and ' the apparent size ' of the moon, but we know that both these expressions are extremely elliptical. The significance of the words " real " and " really " can be determined only by reference to the context in which they are used. Nothing but confusion can result if, in one and the same sentence, we mix up language used appropriately for the furniture of earth and our daily dealings with it with language used for the purpose of philosophical and scientific discussion.

A peculiarly gross example of such a linguistic mix-

[1] Cf ' How easy is that bush supposed a bear ! '

ture is provided by one of Eddington's most picturesque passages :

> I am standing on a threshold about to enter a room. It is a complicated business. In the first place I must shove against an atmosphere pressing with a force of fourteen pounds on every square inch of my body. I must make sure of landing on a plank travelling at twenty miles a second round the sun—a fraction of a second too early or too late, the plank would be miles away. I must do this whilst hanging from a round planet head outward into space, and with a wind of aether blowing at no one knows how many miles a second through every interstice of my body. The plank has no solidity of substance. To step on it is like stepping on a swarm of flies. Shall I not slip through ? No, if I make the venture one of the flies hits me and gives me a boost up again ; I fall again and am knocked upwards by another fly ; and so on. I may hope that the net result will be that I remain steady ; but if unfortunately I should slip through the floor or be boosted too violently up to the ceiling the occurrence would be, not a violation of the laws of Nature, but a rare coincidence. (*N.Ph.W.* 342.)

Whatever we may think of Eddington's chances of slipping through the floor, we must regard his usage of language in this statement as gravely misleading to the common reader. I cannot doubt that it reveals serious confusion in Eddington's own thinking about ' the nature of the physical world '. Stepping on a plank is not in the least like ' stepping on a swarm of flies '. This language is drawn from, and is appropriate to, our daily intercourse with the familiar furniture of earth. We understand well what it is like to step on to a solid plank ; we can also imagine what it would be like to step on to a swarm of flies. We know that two such experiences would be quite different. The plank is solid. If it be securely fixed, it will support our weight. What, then, are we to make of the comparison of stepping *on to a plank with stepping on to a swarm of flies ?* What

can be meant by saying that 'the plank has no solidity of substance'?

Again, we are familiar with the experience of shoving against an obstacle, and with the experience of struggling against a strong head-wind. We know that we do not have 'to shove against an atmosphere' as we cross the threshold of a room. We can imagine what it would be like to jump on to a moving plank. We may have seen in a circus an equestrian acrobat jump from the back of a swiftly moving horse on to the back of another horse moving with approximately the same speed. We know that no such acrobatic feat is required to cross the threshold of a room.[1]

I may seem too heavy-handed in my treatment of a picturesque passage, and thus to fall under the condemnation of the man who cannot see a joke and needs to be 'in contact with merry-minded companions'[2] in order that he may develop a sense of humour. But the picturesqueness is deceptive; the passage needs serious criticism since Eddington draws from it a conclusion that is important. 'Verily,' he says, 'it is easier for a camel to pass through the eye of a needle than for a scientific man to pass through a door. And whether the door be barn door or church door it might be wiser that he should consent to be an ordinary man and walk in rather than wait until all the difficulties involved in a really scientific ingress are resolved.' It is, then, suggested that an ordinary man has no difficulty in crossing the threshold of a room but that 'a really scientific ingress'

[1] Eddington's words suggest that he is standing on a stationary plank and has to land on to another plank that is moving, relatively to himself, with a speed of twenty miles a second. It would be charitable to regard this as a slip, were it not that its rectification would spoil this part of his picture. There is an equally gross absurdity in the statement that he is 'hanging head outward into space'.

[2] See *N.Ph.W.* 336.

presents difficulties.[1] The suggested contrast is as absurd as the use of the adjective 'scientific' prefixed to 'ingress', in this context, is perverse. Whatever difficulties a scientist, by reason of his scientific knowledge, may encounter in becoming a member of a spiritual church, these difficulties bear no comparison with the difficulties of the imagined acrobatic feat. Consequently, they are not solved by the consideration that Eddington, no less than the ordinary man, need not hesitate to cross the threshold of his room. The false emotionalism of the picture is reminiscent of Jeans's picture of human beings standing on 'a microscopic fragment of a grain of sand'. It is open to a similar criticism.[2]

If Eddington had drawn this picture for purely expository purposes, it might be unobjectionable. The scientist who sets out to give a popular exposition of a difficult and highly technical subject must use what means he can devise to convey to his readers what it is all about. At the same time, if he wishes to avoid being misunderstood, he must surely warn his readers that, in the present stage of physics, very little can be conveyed to a reader who lacks the mathematical equipment required to understand the methods by which results are obtained and the language in which these

[1] In the article 'The Domain of Physical Science' (*Science, Religion and Reality*) a similar passage begins as follows:

'The learned physicist and the man in the street were standing together on the threshold about to enter a room.

The man in the street moved forward without trouble, planted his foot on a solid unyielding plank at rest before him, and entered.

The physicist was faced with an intricate problem.' (There follows much the same account of the difficulties as in the passage quoted.)

Eddington here goes on to suggest that the physicist may be 'content to follow *the same crude conception* of his task that presented itself to the mind of his unscientific colleague' (my italics).

[2] See p. 11 above.

results can alone find adequate expression. Eddington's picture seems to me to be open to the objection that the image of a swarm of flies used to explain the electronic structure of matter is more appropriate to the old-fashioned classical conceptions that found expression in a model than to the conceptions he is trying to explain. Consequently, the reader may be misled unless he is warned that nothing resembling the spatial relations of flies in a swarm can be found in the collection of electrons. No concepts drawn from the level of common-sense thinking are appropriate to sub-atomic, i.e. microphysical, phenomena. Consequently, the language of common sense is not appropriate to the description of such phenomena. Since, however, the man in the street tends to think in pictures and may desire to know something about the latest developments of physics, it is no doubt useful to provide him with some rough picture.[1] The danger arises when the scientist uses the picture for the purpose of making explicit denials, and expresses these denials in common-sense language used in such a way as to be devoid of sense. This, unfortunately, is exactly what Eddington has done in the passage we are considering, and indeed, in many other passages as well.

It is worth while to examine with some care what exactly it is that Eddington is denying when he asserts that 'the plank has no solidity of substance'. What are we to understand by "solidity"? Unless we do understand it we cannot understand what the denial of solidity to the plank amounts to. But we can understand "solidity" only if we can truly say that the plank is solid. For "solid" just

[1] Jeans has a happy gift of using such pictures in his purely expository works. See, for example, his image of the postage-stamp, the penny, and Cleopatra's needle, used to illustrate certain proportions of the history of the world—*The Universe Around Us*, p. 342.

is the word we use to describe a certain respect in which a plank of wood resembles a block of marble, a piece of paper, and a cricket ball, and in which each of these differs from a sponge, from the interior of a soap-bubble, and from the holes in a net. We use the word "solid" sometimes as the opposite of "empty", sometimes as the opposite of "hollow", sometimes as the opposite of "porous". We may also, in a very slightly technical usage, contrast "solid" with "liquid" or with "gaseous". There is, no doubt, considerable variation in the precise significance of the word "solid" in various contexts. Further, as is the case with all words, "solid" may be misused, and may also be used figuratively. But there could not be a *misuse*, nor a *figurative* use, unless there were some correct and literal usages. The point is that the common usage of language enables us to attribute a meaning to the phrase "a solid plank"; but there is no common usage of language that provides a meaning for the word "solid" that would make sense to say that the plank on which I stand is not *solid*. We oppose the solidity of the walls of a house to the emptiness of its unfurnished rooms; we oppose the solidity of a piece of pumice-stone to the porous loofah sponge. We do not deny that the pumice-stone is to some degree porous, that the bricks of the wall have chinks and crevices. But we do not know how to use a word that has no sensible opposite. If the plank is non-solid, then what does "solid" *mean*? In the companion passage to the one quoted above, and to which reference was made in a preceding footnote, Eddington depicts the physicist, about to enter a room, as reflecting that 'the plank is not what it appears to be—a continuous support for his weight'. This remark is absurd. The plank appears to be capable of supporting his weight, and, as his subsequent entry into the room showed, it *was* capable

of supporting his weight. If it be objected that the plank is ' a support for his weight ' but not ' a *continuous* support ', I would reply that the word " continuous " is here used without any assigned meaning. The plank appears *solid* in that sense of the word " solid " in which the plank is, in fact, solid. It is of the utmost importance to press the question : If the plank appears to be *solid*, but is really *non-solid*, what does " solid " mean ? If " solid " has no assignable meaning, then " non-solid " is also without sense. If the plank is non-solid, then where can we find an example to show us what " solid " means ? The pairs of words, " solid "—" empty ", " solid "—" hollow ", " solid "—" porous ", belong to the vocabulary of common-sense language ; in the case of each pair, if one of the two is without sense, so is the other.

This nonsensical denial of solidity is very common in popular expositions of the physicist's conception of material objects. The author of a recently published book says : ' A table, a piece of paper, no longer possess that solid reality which they appear to possess ; they are both of them porous, and consist of very small electrically charged particles, which are arranged in a peculiar way.' [1] How are we to understand the statement that the table *no longer* possesses ' the solid reality ' which it appears to possess ? The context of the statement must be taken into account. The sentence quoted occurs in a summary of the view of the physical world according to classical physics. It immedi-

[1] Ernst Zimmer : *The Revolution of Physics*, trans. by H. Stafford Hatfield, 1936, p. 51. I have not been able to consult the German original, so I am unable to determine whether ' solid reality ' is a good rendering of Zimmer's meaning. Certainly the juxtaposition of the two words is unfortunate, but is evidently judged to be appropriate at least by his translator.

ately follows the statement: 'This picture formed by the physicists has one great drawback as compared with the picture formed by the non-scientific man in the street. It is much more abstract.' In a later chapter we shall find reason to consider carefully what is meant by 'more abstract'. Here we are concerned only with the suggestion that the non-scientific man forms one 'picture' of the material world and the scientist another. There are, then, two pictures. Of what, we must ask, are they pictures? Where are we to find application for the words "solid reality", which we may not use with reference to the table? Again we must ask: If the table is non-solid, what does "solid" mean?

No doubt the author had in mind the nineteenth-century view of the ultra-microscopic world as consisting of solid, absolutely hard, indivisible billiard-ball-like atoms, which were assumed to be solid and hard in a perfectly straightforward sense of the words "solid" and "hard". If so, it would be more appropriate to say that the modern physicist no longer believes that the table *consists* of solid atomic balls, than to say that 'the table no longer possesses solid reality'. There is, indeed, a danger in talking about *the table* at all, for the physicist is not, in fact, concerned with tables. The recent habit of talking as though he were is responsible for much confusion of thought. It leads Eddington into the preposterous nonsense of the 'two tables'. This view will be familiar to every one who is interested in the philosophy of the physicists. Nevertheless, it is desirable to quote a considerable part of Eddington's statement, since it is important to examine his view in some detail.

I have settled down to the task of writing these lectures and have drawn up my chairs to my two tables. Two tables! Yes; there are duplicates of every object about me—two tables, two chairs, two pens.

. . . One of them has been familiar to me from earliest years. It is a commonplace object of that environment which I call the world. How shall I describe it? It has extension; it is comparatively permanent; it is coloured; above all, it is *substantial*. . . . Table No. 2 is my scientific table. It is a more recent acquaintance and I do not feel so familiar with it. . . . My scientific table is mostly emptiness. Sparsely scattered in that emptiness are numerous electric charges rushing about with great speed; but their combined bulk amounts to less than a billionth of the bulk of the table itself. Notwithstanding its strange construction it turns out to be an entirely efficient table. It supports my writing paper as satisfactorily as table No. 1; for when I lay the paper on it the little electric particles with their headlong speed keep on hitting the underside, so that the paper is maintained in shuttlecock fashion at a nearly steady level. If I lean upon this table I shall not go through; or, to be strictly accurate, the chance of my scientific elbow going through my scientific table is so excessively small that it can be neglected in practical life . . . There is nothing *substantial* about my second table. It is nearly all empty space—space pervaded it is true by fields of force, but these are assigned to the categories of 'influences', not of 'things'.[1]

There is so much to criticize in this passage that it is difficult to know where to begin. Probably Eddington's defence against any criticism would be that this is one of the passages in which he 'was leading the reader on'[2] (presumably—to put it vulgarly—'up the garden path'), and that consequently it must not be taken as giving 'explicit statements' of his philosophical ideas. But he has nowhere expounded his philosophical ideas in non-popular language. Moreover, the mistakes are so frequently repeated in his writings and seem to be so inextricably bound up with his philosophical conclusions, that it is inevitable that these mistakes should be submitted to detailed criticism.

Perhaps the first comment that should be made is that

[1] *N.Ph.W.* xi, xii, xiii. I assume the reader's familiarity with the rest of the chapter in which this passage occurs.

[2] *N.P.Sc.* 291, and see p. 98 below.

Eddington takes quite seriously the view that there are *two tables*; one belongs to 'the external world of physics', the other to 'a world of familiar acquaintance in human consciousness'. Eddington's philosophy may be regarded as the outcome of a sustained attempt to answer the question: How are the two tables related to one another? It never seems to occur to him that the form of the question is absurd. In answering the question he is hampered from the start by his initial assumption that the tables are *duplicates* of each other, i.e. that it really isn't nonsensical to speak of two *tables*. I hazard the conjecture that Eddington is an inveterate visualizer,[1] and that once he has committed himself to the language of 'two tables' he cannot avoid thinking of one as the shadow and of the other as the substance. (In this sentence, I have used the word "substance" simply as the correlative of "shadow". This usage has undoubtedly influenced Eddington's thinking on this topic.) It is evident that the scientific table is to be regarded as the shadow. There are statements that conflict with this interpretation, but Eddington does not leave us in doubt that, whenever he is using the language of *shadowing*, it is the scientific table that is a shadow of the familiar table. It is true that he

[1] The following passage is significant: 'When I think of an electron there rises to my mind a hard, red, tiny ball; the proton similarly is neutral grey. Of course the colour is absurd—perhaps not more absurd than the rest of the conception—but I am incorrigible' (*N.Ph.W.* xviii).

Cf. also, 'I am liable to visualize a Test-Match in Australia as being played upside down' (*N.P.Sc.* 314). Perhaps this habit is responsible for the queer statement (quoted above, p. 48) that the feat of entering his study has to be accomplished whilst he is 'hanging from a round planet head outward into space'. Only, in that case, he has forgotten that his study would be hanging outward the same way. What is more important is that he has created a difficulty out of a mode of speech.

says, ' I need not tell you that modern physics has by delicate test and remorseless logic assured me that my second scientific table is the only one which is really there—wherever " there " may be '. Elsewhere he says, ' Our conception of the familiar table was an illusion ' (*N.Ph.W.* 323). These discrepancies result from the deep-seated confusions out of which his philosophy springs ; they will be examined in the following chapters. At present we are concerned with the view—in conflict with the statements just quoted—that the scientific table is a shadow. ' In the world of physics ', he says, ' we watch a shadowgraph performance of the drama of familiar life. The shadow of my elbow rests on the shadow table as the shadow ink flows over the shadow paper. It is all symbolic, and as a symbol the physicist leaves it ' (xvi). Elsewhere he suggests that physicists would generally say that ' the matter of this familiar table is *really* a curvature of space ', but that is a view difficult to reconcile with either of the statements we are considering now.

Certainly there is much in the passage about the two tables that seems to conflict with the view of the scientific table as a shadow. It is said to be ' mostly emptiness ', but scattered in the emptiness are numerous electric charges whose ' combined bulk ' is compared in amount with ' the bulk of the table itself '. Is ' the table itself ' the familiar table ? I think it must be. But the comparison of the *two* bulks is surely nonsensical. Moreover, a shadow can hardly be said to have *bulk*. Yet Eddington insists that the two tables are ' parallel '—an odd synonym, no doubt, for a ' shadow '. He contrasts the scientific *table*, which has a familiar *table* parallel to it, with the scientific electron, quantum, or potential, which have no familiars that are parallel. Of the latter he says that the physicist is scrupulously careful to

guard them 'from contamination by conceptions borrowed from the other [i.e. the familiar] world'. But if electrons, belonging to world No. 2, are to be scrupulously guarded from contamination by world No. 1, how can it make sense to say that they 'keep on hitting the underside' of a sheet of paper that, indubitably, is part of the familiar furniture of earth? It is Eddington who reintroduces contamination when he talks in this fashion, and he does so because he supposes that there is a scientific table parallel to the familiar table. I venture to suggest that it is as absurd to say that there is a scientific table as to say that there is a familiar electron or a familiar quantum, or a familiar potential. Eddington insists upon the lack of familiar parallels in the latter cases; surely he is justified in doing so. What is puzzling is his view that there are parallel *tables*. It suggests a return to the days when physicists demanded a model; 'the physicist', says Eddington, 'used to borrow the raw material of his world from the familiar world, but he does so no longer' (xv). But if the 'scientific table' is to be regarded as the product of the 'raw material of the scientific world', how can it be regarded as parallel to the familiar table? Eddington seems unable to free himself from the conviction that the physicist is concerned with things of the same nature as the things of the familiar world; hence, *tables* are to be found in both world No. 1 and world No. 2. There is a statement in his exposition of 'The Downfall of Classical Physics' that shows how deep-rooted this conviction is. 'The atom,' he says, 'is as porous as the solar system. If we eliminated all the unfilled space in a man's body and collected his protons and electrons into one mass, the man would be reduced to a speck just visible with a magnifying glass' (*N.Ph.W.* 1–2). The comparison is useful enough; the absurdity comes from speaking of the

speck as a *man*. If this statement stood alone, it might well be regarded as an expository device. But the constant cropping up of the parallel tables shows that Eddington does not regard it as absurd to think of the reduction as still leaving a *man*. When, later in the book, he is expounding the conception of space required by relativity theory, he points out that our difficulty in conceiving it is due to the fact that we are 'using a conception of space which must have originated many millions of years ago and has become rather firmly embedded in human thought' (81). He adds: 'But the space of physics ought not to be dominated by this creation of the dawning mind of an enterprising ape.' It seems to me that in allowing himself to speak of the speck as a man, Eddington is allowing himself to be thus dominated. It is true that, in the statement just quoted, Eddington was speaking of relativity physics, but I do not think that 'the creation of the dawning mind of an enterprising ape' is any more appropriate to the conception of space in atomic physics. To this point we must return later.[1] It must suffice at the moment to insist that a *man* is an object belonging to the familiar world, and has no duplicate in 'the scientific world'.

Perhaps we may be convinced of the absurdity of the notion that there are 'duplicates of every object' in the familiar world, if we return to the consideration of the description of a familiar scene with which this chapter opened. I spoke there of 'blue curtains', of a crimson and scented rose, of a bruised leg. Neglecting at present the consideration of the bruised leg, which—judging by Eddington's account of the adventures of an elephant[2]—is beneath the notice of a scientist, we may ask what duplicate of *blue* is to be found in the scientific world. The answer is

[1] See below, p. 201. [2] See below, p. 92–3.

that there is no duplicate. True that it has a 'counterpart', but that is a very different matter. The counterpart of colour is 'its scientific equivalent electromagnetic wave-length' (88). 'The wave', says Eddington, 'is the reality —or the nearest we can get to a description of reality; the colour is mere mind-spinning. The beautiful hues which flood our consciousness under stimulation of the waves have no relevance to the objective reality.' It is obvious that here Eddington is regarding the scientific world as 'the objective reality'; the familiar world is subjective. This does not square with the view that the scientific world is the shadow of the familiar world, but it is hopeless to attempt to extract from Eddington any consistent view of their relation. With this difficulty, however, we are not at the moment concerned. The point is that Eddington firmly extrudes *colour* from the scientific world, and rightly so. But the *rose* is coloured, the *table* is coloured, the *curtains* are coloured. How, then, can that which is not coloured duplicate the rose, the curtains, the table? To say that an electromagnetic wave-length is coloured would be as nonsensical as to say that symmetry is coloured. Eddington does not say so. But he has failed to realize that a coloured object could be *duplicated* only by something with regard to which it would not be meaningless to say that it was coloured.

It seems to me that in his theory of the duplicate worlds Eddington has fallen into the error of which Berkeley accused the Newtonians. Berkeley was strongly convinced that the sensible world[1] was pre-eminently a *seeable* world. No doubt he over-stressed the sense of sight at the expense of the other senses, but in the climate of opinion in which

[1] I use the phrase "sensible world" here with the same denotative reference as Eddington's phrase "familiar world".

he was living this over-emphasis served a useful purpose. Consider the following passage:

> How vivid and radiant is the lustre of the fixed stars! how magnificent and rich that negligent profusion, with which they appear to be scattered throughout the whole azure vault! Yet if you take the telescope, it brings into your sight a new host of stars that escape the naked eye. . . . Is not the whole system immense, beautiful, glorious beyond expression and beyond thought? What treatment then do those philosophers deserve, who would deprive these noble and delightful scenes of all reality? How should those principles be entertained, that lead us to think all the visible beauty of the creation a false imaginary glare?[1]

It seemed to Berkeley that the metaphysics of Descartes and Newton resulted in the description of a 'real world' that had all the properties of the sensible world except the vital property of being seeable. 'Ask a Cartesian,' he said,[2] 'whether he is wont to imagine his globules without colour. Pellucidness is a colour. The colour of ordinary light of the sun is white. Newton in the right in assigning colour to the rays of light.[3] A man born blind would not imagine Space as we do. We give it always some dilute, or duskish, or dark colour—in short, we imagine it as visible, or intromitted by the eye, which he would not do.' *Black* also is, in the sense required, a *colour*; a 'dark world' is no less a world apprehensible only by sight than a 'bright world' is. But the pure mathematician cannot take note of colour. Hence, under the influence of the *Mathematical Principles of Natural Philosophy* and of the rapidly developing science of optics, Berkeley's contemporaries looked to the principles of optics to account for the *seeability* of things. It is Berkeley's merit to have realized that the Cartesian–Newtonian philoso-

[1] *Three Dialogues between Hylas and Philonous* (Second Dialogue).
[2] *Commonplace Book*, ed. by G. A. Johnston, p. 50.
[3] But see below, p. 63.

phers, seeking to account for a *seeable* world, succeeded only in substituting a world that could in no sense be *seen*. He realized that they had substituted a theory of optics for a theory of visual perception. The outcome of this mistake is a duplication of worlds—the Image-World, sensibly perceived by men, the Real-World apprehended only by God. Newton is quite explicit on this point:

> Was the Eye contrived without Skill in Opticks, and the Ear without Knowledge of Sounds? . . . Is not the sensory of Animals that place to which the sensitive Substance is present, and into which the sensible Species of Things are carried through the Nerves and Brain, that there they may be perceived by their immediate presence to that Substance? And these things being rightly dispatch'd, does it not appear from Phaenomena that there is a Being incorporeal, living, intelligent, omnipresent, who in infinite Space, as it were in his Sensory, sees the things themselves intimately, and thoroughly perceives them, and comprehends them wholly by their immediate presence to himself: Of which things the Images only carried through the Organs of Sense into our little Sensoriums, are there seen and beheld by that which in us perceives and thinks.[1]

Berkeley saw the absurdity of this duplication; he failed to realize that it was rendered necessary only by the confusion of the theory of optics with the theory of vision. He saw that the question—How is perception possible?—is devoid of sense; he saw that it is no less absurd to look to physics for an answer to the question. Unfortunately he accepted the account of objects of sight that was provided by the Optical Theory, and thus abolished the duplication of worlds only by locating (however indirectly) 'the things by me perceived' in the Mind of the Infinite Spirit. Newton had transferred colours from *things seen* into 'our little Sensoriums'; he conceived them as optical Images; accordingly, there were still required the things in them-

[1] *Opticks*, Query 28. (Edition reprinted 1931, p. 370.)

selves *of which* they were Images. These things must be found in the Sensory of God. Berkeley abolished the Images but only by carrying to a conclusion the absurdities initiated by the use of the language of Optics.

The achievement of Newton in the theory of Optics was that by his discovery of differently refrangible rays he discovered *measurable correlates of colour*; he thereby made the use of quantitative methods possible in a domain which would otherwise be excluded from the scope of physics. His extremely confused metaphysics is the result of his refusal to admit that there is anything in the perceived world except the measurable correlates, which ought, accordingly, to be regarded as the correlates of nothing. Newton saved himself from this manifest contradiction by having resort to a transmissive theory of Nature, and thus to a causal theory of perception. Allowing for the difference of phraseology we may surely see in the following quotation from Newton an anticipation of Eddington's theory of the sensible world.

The homogeneal Light and Rays which appear red, or rather make Objects appear so, I call Rubrifick or Red-making; those which make Objects appear yellow, green, blue, and violet, I call Yellow-making, Green-making, Blue-making, Violet-making, and so of the rest. And if at any time I speak of Light and Rays as coloured or endued with Colours, I would be understood to speak not philosophically and properly, but grossly, and accordingly to such Conceptions as vulgar People in seeing all these experiments would be apt to frame. For the Rays to speak properly are not coloured. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour. For as Sound in a Bell or musical String, or other sounding Body, is nothing but a trembling Motion, and in the Air nothing but that motion propagated from the Object, and in the Sensorium 'tis a Sense of that Motion under the Form of Sound; so Colours in the Object are nothing but a Disposition to reflect this or that sort of Rays more copiously than the

Rest ; in the Rays they are nothing but their Dispositions to propagate this or that Motion into the Sensorium, and in the Sensorium they are Sensations of those Motions under the Forms of Colours.[1]

This wholly fallacious argument has been strangely persuasive to physicists. Sensible qualities have no place in the world ; they are *nothing but* ' dispositions to propagate this or that motion into the Sensorium '. There they undergo a transformation, not in the mathematical sense of that word, but a strange transformation indeed—a metamorphosis of ' the external world of physics ' into ' a world of familiar acquaintance in human consciousness '.[2] The transformation remains inexplicable. Small wonder that Mr. Joad, reflecting upon the philosophical consequences of ' modern physics ', exclaimed in perplexity, ' But, if I never know directly events in the external world, but only their alleged effects on my brain, and if I never know my brain except in terms of its alleged effects on my brain, I can only reiterate in bewilderment my original questions : " What sort of thing is it that I know ? " and " Where is it ? " '[3] Such perplexity can be resolved only by reconsidering the assumptions that led to the asking of these unanswerable questions. We shall find that the problem of perception, in this form, arose only because we have allowed the physicists to speak of a ' real world ' that does not contain any of the qualities relevant to perception. To adopt the striking phrase of Professor E. A. Burtt, we have allowed the physicists ' to make a metaphysic out of a *method* '. In so doing they have forgotten, and philosophers do not seem to remember, that their method has been designed to facilitate investigations originating from a study of ' the furniture of the earth '.

[1] *Opticks*, Bk. I, Pt. II (1931 ed., pp. 124–5). [2] See *N.Ph.W.* xiv.
[3] *Aristotelian Society :* Supp. Vol. IX, p. 137.

Chapter IV

'THE SYMBOLIC WORLD OF PHYSICS'

'It is the truth which makes us free, and they only are in bondage who are ignorant of the truth, or refuse to admit it. If therefore it be, that there is no external world, common language is indeed extremely corrupt; but they only are involved in this corruption who know not this truth, or deny the evidence of it. And the same argument by which it is demonstrated to be a truth, proves the use of all language unclean to such as these. For such are servants to the power of a corrupt language, and know not their right of freedom from it; and this makes them guilty of all the errors which it supposes. Whereas those who know and believe this truth, are free to use any way of speaking, wherein this truth is not formally or directly contradicted, without being accountable for the corruption of human language.'

A. COLLIER: *Clavis Universalis* (1713)

'SCIENCE', says Eddington, 'aims at constructing a world which shall be symbolic of the world of commonplace experience' (*N.Ph.W.* xv). To this view of the aim of science Eddington does in the main adhere. It is of the greatest importance for our purpose to consider what this aim involves. At the outset it must be remembered that Eddington uses "science" as a synonym for "exact science", although, in the above statement, mathematics is presumably excluded. According to this view the biological sciences are not strictly scientific; they are to be included in the domain of science only in so far as they can be regarded as exact. Nothing that is not metrical in character is sus-

ceptible of scientific treatment. Eddington does in effect restrict science to mathematical physics. His conception of the aim of science may be contrasted with that of Niels Bohr, who conceives that 'the task of science is both to extend the range of our experience and to reduce it to order'.[1] According to Eddington its task is to construct a symbolic world.

The first question to be asked is what is the point of this construction of a symbolic world. Its aim can hardly be to express in language which only mathematicians can understand the occurrences with which every one is familiar. If it were, the scientist would be a curious kind of poet, or perhaps a pure mathematician. There is some truth in the view that the thinking of a mathematical physicist is more akin to the creative activity of the artist than to the processes of thought of a plodding photographer. Nevertheless, physics is not art. The mathematician, Eddington says, 'is the professional wielder of symbols'. But the physicist is not a pure mathematician. He starts from what is sensibly observed and must return to what is sensibly observed. Eddington himself admits that 'the whole scientific inquiry starts from the familiar world and in the end it must return to the familiar world'. How, then, is the symbolic construction at which physics aims related to the familiar world? There would seem to be three alternatives: (1) the construction is an imitation of the world; (2) the construction is more real than (or truer than?) the familiar world; (3) the construction is for the sake of correlating certain selected elements in the familiar world, in order that the range of our experience may be extended and what is sensibly experienced may be ordered. Eddington's statement of the aim of science definitely rules out the third alternative, although

[1] *Atomic Theory and the Description of Nature*, p. 1.

I do not suppose that he would wholly wish to reject it. He seems to adopt both the first and second alternatives. It may perhaps be said that Eddington holds that the symbolic construction is an imitation of the familiar world which is also something more profound than that which is imitated. One is reminded of Aristotle's use of the conception of μίμησις. In tragedy, he said, 'we imitate men as better than they are'. But it is not easy to ascertain whether this is the sort of meaning Eddington attaches to the word "imitation" when he speaks of the method 'by which we build up from its own symbolic elements a world which will imitate the actual behaviour of the world of familiar experience' (*N.Ph.W.* 249). Nor does he hold that the researches of the physicists give us 'the real truth' about the familiar world. In his famous paper, 'The Domain of Physical Science',[1] he pointed out that 'physics does in practice give a preference to the view of the microbe over that of the man', and that the physicist is apt to hold that 'the microscopic' view contains the real truth as to what is actually occurring'. But Eddington himself held that physics 'lays undue stress on the microscopic point of view' unless the limitation is recognized as required by the methods of science. It is interesting to notice that Eddington's warning against 'undue insistence on microscopic analysis' was, at this period of his writing, connected with his recognition that quantum phenomena were not amenable to 'analysis of this kind'. There is no hint of any connection between this rejection of the 'microscopic view' as fundamental and a recognition of the fact that the physicist must test his theories by his sensible experiences. As we shall see later[2] Eddington desired only to insist that the limitations of

[1] *Science, Religion, and Reality*, see pp. 195–7.

[2] See below, p. 116.

physics must be borne in mind when we attempt to evaluate the domain of physical science. Meanwhile, it is enough for him to insist upon the symbolic construction itself.

We must attempt to discover how the construction is achieved, what elements enter into it, and how the completed construction is related to the familiar world. Success in this attempt is not easy owing to Eddington's failure to make clear the level from which, in any given passage, he is speaking. Possibly he does not himself recognize that there are different levels.

There are three main points to consider: Eddington's conception of World-building and the part played by the cyclic method; his distinction between three different kinds of laws; his conception of the subject-matter of physics. It is convenient to depart from Eddington's own order of treatment and to consider the second point first.

Eddington lays great stress upon the distinction between three kinds of laws of Nature. The clearest indication I have been able to find of how Eddington uses the expression "laws of Nature" is the following statement:

> I do not think we should ever have made progress with the problem of inference from our sensory experience, and theoretical physics would never have originated, if it were not that certain regularities and recurrencies are noticeable in sensory experience. We call these regularities of experience laws of Nature. (*N.P.Sc.* 8.)

Probably every one would agree that the discovery of a considerable number of such regularities and recurrences is a precondition of science. By that I mean that until some regularities have been noted, the sort of questions that interest a scientist would not have been asked. We shall see later how important it is to bear in mind that *science* is not a *person* who can state in advance what he intends to do and how he proposes to carry out

his intention. Science is the work of *scientists*, who, profiting by each other's labours, come gradually to achieve an agreed body of knowledge, and in the course of this achievement continually develop new and more powerful technical methods. The natural scientist observes, formulates hypotheses, performs experiments, and verifies his theoretical constructions. A scientific law worthy of the name of a Principle, of being dignified by capitals—such as the Second Law of Thermodynamics or the Law of Gravitation—is achieved only by the labours of scientists working within a certain context of agreed theory, subject no doubt from time to time to considerable revision, but capable of being taken in the main as the basis for further advance. To question *one* physical law is possible only if there are *other* relevant laws that are not at the moment also being questioned. Otherwise, the questions asked could not receive any answer. The development of a science does not in the least resemble the building of a house, or of a palace, or of a planned garden-suburb. There is nothing in its development comparable to a single foundation upon which, once well and securely laid, the building may be erected by the labours of many workmen, with or without the control of a master-builder. Eddington has himself given an illuminating description of scientific discovery as analogous to the fitting together of the pieces of a jig-saw puzzle. Such a process is extremely unlike the process of building a house or of planning a city.

It may be objected that I have been indulging in a digression. Such an objection would be mistaken. My purpose has been to emphasize the point that the distinction between different *kinds* of laws of Nature (in the sense in which Eddington uses this phrase) can be made only at a com-

paratively advanced stage in the development of the natural sciences. 'The laws of Nature,' Eddington says, 'divide themselves into three classes: (1) identical laws, (2) statistical laws, (3) transcendental laws' (*N.Ph.W.* 244). The conservation laws, the law of gravitation, the laws of electric and magnetic force, provide examples, according to Eddington, of identical laws. He says that they are truisms. The gas laws, relating to the behaviour of collections of individuals, and the second law of thermodynamics are examples of statistical laws. Transcendental laws, if there are any, would be 'genuine laws of control in the physical world'. Eddington has sometimes suggested that if there are any transcendental laws they are the laws of atomic structure and of quantum phenomena, and that these are true laws of governance.[1] But he would now (1937) regard quantum laws as having been definitely placed in the class of statistical laws.[2] He holds that statistical laws do not presuppose controlling laws.[3] This seems to me to be extremely doubtful. I should have supposed that there must be at least one controlling law, but I am not competent properly to argue the question. Nor is it essential to do so, since our interest lies in the purport of these distinctions and in the use Eddington makes of identical laws in his game of world-building.

The well-known chapter on 'World-Building', in the *Nature of the Physical World* (Chapter X), should be studied in close connexion with Chapter VI, 'Gravitation: The Law', and with Chapter VII, 'Gravitation: The Explanation'. A full exposition of these chapters cannot be given here. It must suffice to indicate the line of thought pursued

[1] See *Mathematical Theory of Relativity* (2nd ed.), p. 262.

[2] See *Relativity Theory of Protons and Electrons*, p. 329.

[3] See p. 92 below.

by Eddington. He proclaims very clearly what he proposes to do—to build a World by using 'as little specialized material as possible'. The world to be thus built is 'a physical world which will give a shadow-performance of the drama enacted in the world of experience'. Certain conditions are to be observed. 'Success in the game of world-building', he says, 'consists in the greatness of the contrast between the specialized properties of the completed structure and the unspecialized nature of the basal material.'[1] He professes to use only two elements of building material, *relata* and *relations*—'The relations unite the relata; the relata are the meeting-points of the relations.' This seems modest material enough. If it indeed be all that is required, then Eddington's claim would be justified—that 'a more general starting-point' could hardly be conceived. Unfortunately, however, for this claim, it is surely clear that if the relata are to be used as building materials, they must be distinguishable one from another. To distinguish them a monomark is to be assigned to each relatum. The monomark consists of four numbers. The term 'monomark' is no doubt used to show that the identification sign is wholly arbitrary. The next step is to postulate 'some kind of relation of likeness between some of the relations' in order that we may be able 'to link the whole into a structure'. It must also be arranged that 'the monomarks are so assigned as to give an indication of contiguity'. Finally we are told that a little manipulation will enable us to derive 256 (i.e. 4^4)[2]

[1] Cf. *Mathematical Theory of Relativity*, p. 237: 'In the game of world-building we lose a point whenever we have to ask for extraordinary material specially prepared for the end in view.'

[2] Cf. *Mathematical Theory of Relativity*, p. 226. 'That the relation of displacement between A and B amounts to such-and-such a quantity conveys no absolute meaning; but that the relation of displacement

numerical coefficients which ' will give a numerical measure of the structure surrounding the initial relatum.' These 256 measures of structure may be reduced to 16, by omitting duplicates and by eliminating as ' useless lumber ' any elements that will not be required in building a world that will shadow the familiar furniture of the earth. Of these 16 coefficients for each relatum, ten are used for constructing geometry and mechanics. These are the ten quantities that must be identified with the ten gravitational potentials required by Einstein's law of gravitation. Out of the remaining six, electromagnetism is to be constructed—three components of electric intensity and three components of magnetic force. These building operations, Eddington says, do not extend to ' the microscopic structure of the world ', but he claims that ' in regard to what is called *field-physics* the construction is reasonably complete '.

This game of world-building is an amusing one. Eddington plays it skilfully but he does not play it fairly. In assigning the monomarks he has slipped in ' specially prepared material ' an open demand for which would have lost him ' a point in the game '. It is possible to assign a monomark (a, b, c, d) to Bernard Shaw that will distinguish him from H. G. Wells to whom has been assigned the monomark (e, f, g, h) ; for Bernard Shaw is already distinguishable from H. G. Wells, independently of the assignment of their respective monomarks. A monomark is an arbitrarily chosen name serving uniquely to indicate the individual to which it has been assigned, just because that individual is already distinguishable in other respects from other indi-

between A and B is " equivalent " to the relation of displacement between C and D is (or at any rate may be) an absolute assertion. Thus four points is the minimum number for which an assertion of absolute structural relation can be made.'

viduals and, further, to no two individuals is the *same* monomark assigned. But Eddington has not provided any way of securing that the relata should be mutually distinguishable. It is clearly absurd to try to assign monomarks to distinguish one from another relata that are in fact undistinguishable. In the next step he deserves to lose another point since he has failed to lay down any condition securing the inclusion of a serial relation among the relations between the relata. He admits that we must postulate 'some kind of relation of *likeness* between some of the relations', and thereupon he assumes that it will be possible to pick out two relata standing to each other in a given relation and to pick out 'close at hand' other relata standing to each other in a 'like' relation. 'The comparability that has to be assumed axiomatically', he says, 'is a merely qualitative discrimination of likeness and unlikeness.' But this provides only that the relation shall be symmetrical and transitive. But Eddington has admitted :

> 'Let me confess at once that I do not know what I mean here by "very close together". As yet space and time have not been built. Perhaps we might say that only a few of the relata possess relations whose comparability to the first is definite, and take the definiteness of the comparability as the criterion of contiguity. I hardly know.'

But what entitles him to suppose that a transitive symmetrical relation is more likely to hold between relata 'very close together' than between relata not very close together? Further, we require not merely qualitative contiguity but serial order. Either the transitive symmetrical relation must be one capable of existing in degrees of *greater or less*, or some condition securing serial order must be laid down independently of that relation. Bertrand Russell has suggested a method based upon the first assumption; for example, the fundamental relation might be taken to be

one involving eight points, and be of the form '*abcd* is more nearly a parallelogram than *efgh*'.[1] It is, however, impossible to extract the conditions required for such a relation from Eddington's provision of building material.[2] He contents himself with the significant admission: 'The building at this point shows some cracks, but I think it should not be beyond the resources of the mathematical logician to cement them up.' The admission is significant for two reasons. First, it reveals the game of world-building as simply a logical exercise; it consists in constructing a geometry, i.e. a 'space' in the strict sense in which a pure geometer would speak of 'a space', subject perhaps to the condition that the 'space' thus constructed should be suitable for subsequent use by a physicist. Secondly, the admission shows that there are 'cracks' in the building, which the mathematical logician is to be asked to fill up. But, as Mr. R. B. Braithwaite has pointed out, 'even the mathematical logician cannot make cement without lime'.[3] Eddington has signally failed to provide the 'lime'. It seems, then, reasonable to urge against Eddington that his attempt to derive by pure logic 256 coefficients that will 'give a numerical measure of the structure surrounding the initial relatum' can hardly be regarded as successful.

[1] *Analysis of Matter*, p. 105. The reader will find Russell's discussion in Chapters X and XI of this book very helpful. I am much indebted to it.

[2] In his technical discussion of what is virtually the same problem Eddington does show clearly that he is attempting to derive the metrical properties of *a space* out of its ordinal properties by means of an 'axiom of parallel displacement'. See *Mathematical Theory of Relativity*, § 98.

[3] *Mind*, Oct. 1929 (N.S. 152), p. 425. The article, from which this remark is quoted, is the best discussion of Eddington's Gifford Lectures with which I am acquainted.

It is important and not difficult to see why Eddington calls this exercise 'the game of world-building'. His aim is to make a construction in which the metrical, gravitational, and electromagnetic fields are all included. We may criticize the way in which Eddington has played the game, we may accuse him of some sharp practices, but we do not thereby deny that, *given the provision of adequate building material*, such an inclusive construction could be made. To what extent success in such an enterprise is possible, I do not presume to judge, but for our purposes we may willingly grant the possibility. What is important is the conclusion Eddington draws from the result of his building operations. He reports,

> We build the quantities enumerated above ; and they obey the great laws of field-physics *in virtue of the way in which they have been built.* That is the special feature ; the field laws—conservation of energy, mass, momentum and of electric charge, the law of gravitation, Maxwell's equations—are not controlling laws. They are truisms. Not truisms when approached in the way in which the mind looks out on the world, but truisms when we encounter them in a building up of the world from a basal structure.

It is fundamental to Eddington's philosophy of physics to maintain that the field laws are truisms. To say that a law is a 'truism' means that the law states a relation between terms which follows from the way in which the terms are defined. To achieve this result Eddington strives to show that physics uses a cyclic method. 'The definitions of physics', he says, 'proceed according to the method immortalized in "The House that Jack built".' Every fundamental term in physics is thus regarded as defined in terms of another term which is defined in terms of another term, and so on, until a cycle has been completed. His list of terms is—*potential, interval, scale, matter, stress, potential.* He elaborates his use of the cyclic method in the chapter

entitled ' Pointer-Readings ', which is of central importance for his philosophy of science as issuing in a metaphysic. From this point of view we shall have to consider it later. At present we are concerned to notice that the cyclic method and the game of world-building go together and are open to the same criticisms. They are both devices used for establishing the contention that the field laws are truisms —a contention that has an ulterior purpose. But the contention cannot be maintained in the sense required to justify the conclusions Eddington seeks to derive from it. Indeed, it seems plausible only so long as we ignore the distinction between a logical analysis of a completed scientific scheme and the procedure whereby the scheme has been gradually established. Eddington has been able so to build his world only because, at the present stage of the development of the physical sciences, he could take for granted the field laws and could thus select just those hypotheses that are necessary and jointly sufficient to entail Maxwell's laws of electromagnetism. It is of vital importance, however, not to forget that these laws had been originally discovered and established only as the result of experimental investigations proceeding by means of the tentative formulation of provisional hypotheses and the subsequent verification, by experimental testing, of these hypotheses.

Properly to understand the error in Eddington's conception of the significance of world-building, it is necessary to examine with some care the manner of his approach to physical science and his consequent derivation of the philosophical implications of physics.

We have seen that Eddington believes the aim of science to be the construction of ' a world which shall be symbolic of the world of commonplace experience '. He has also said that speaking broadly we may say that ' the task of science

is to infer knowledge of external objects from a set of signals passing along our nerves' (*N.P.Sc.* 6). I do not think that these views are wholly incompatible. Indeed, taken together, they show how completely Eddington rejects the view that the aim of science is to correlate our experiences in an orderly manner. The basic assumption upon which his conception of the nature of science rests is that the 'external world'[1] is inferred from 'a fanciful story' based upon 'a set of signals passing along our nerves'. The process of inference is regarded as the process of decoding a cryptogram. In developing this notion Eddington plunges into metaphors and absurdities that must be considered in the next two chapters. Meanwhile we must notice that the symbolic world of physics is constructed by decoding the messages given to perceptual consciousness. We have seen that Eddington admits that 'theoretical physics would never have originated' had there not been noticeable regularities in our sensory experiences. These regularities, it will be remembered, were called by Eddington 'laws of Nature'. It is doubtful whether they can be assigned to any of the three classes recognized by Eddington in his discussion of *kinds* of laws. They are certainly not truisms. They can hardly be regarded as statistical laws. It would be too annoying for Eddington if they were to turn out to be 'controlling laws', i.e. transcendental laws. Yet, whatever they may be, these laws are of fundamental importance. It will be convenient for our purpose to call them 'natural laws', as distinguished from 'Laws of Nature' in the sense in which the electromagnetic laws are regarded by Eddington as Laws of Nature.

[1] What meaning precisely is to be attached to Eddington's use of the phrase "external world" is by no means easy to discover. This topic will be discussed in the next chapter.

An example of a natural law (in the sense just now indicated) is that a poker heated in an ordinary fire becomes red ; another is that a lump of sugar dropped into a cup of tea dissolves ; another, that the pressure of a gas increases with its temperature. None of these laws is stated here with the precision that any elementary student of the physical sciences would demand to-day. Nevertheless, as thus stated they provide examples of those ' recurrences and regularities of experience ' upon which alone science can be based and from which its development must proceed. In his popular writings Eddington has made no attempt to explain the distinction between natural laws and Laws of Nature (as used above). Although, as we have seen, he recognizes the basic importance of natural laws, he is not interested in them. His lack of interest is understandable enough. Eddington is a mathematical physicist, and, moreover, he is in a hurry to construct a symbolic world that can be subsequently used for the purposes of his philosophy. But, although understandable, this lack of interest is to be regretted. The common reader can hardly be expected to realize that the distinction between natural laws and Laws of Nature is not a distinction between two *kinds of law*, as the distinction between Jerseys and Alderneys is a distinction between two *kinds of cow* ; it is a distinction between *two different usages* of the word " law ". Almost it seems as though Eddington were taking advantage of our ignorance to foist upon us a philosophical theory in the guise of an interpretation of science.

To understand the difference in the two usages of the word " law " it is helpful to consider the two points of view from which physics may be regarded. These are the inductive and the deductive point of view. Naturally the mathematical physicist is interested almost exclusively in

the latter point of view. For, as Einstein has pointed out: 'Advances in scientific knowledge must bring about the result that an increase in formal simplicity can only be won at the cost of an increased distance or gap between the fundamental hypotheses on the one hand, and the directly observed facts on the other. Theory is compelled to pass more and more from the inductive to the deductive method, even though the most important demand to be made of every scientific theory will always remain that it must fit the facts.'[1] Eddington desires to start from a single, generalized fundamental law and from it to deduce the quantities that are subsequently to be given a 'physical meaning', i.e. are to be identified with the results of experiment.[2] Apart from the necessity of giving a physical meaning, his procedure would be hardly distinguishable from pure mathematics.

The inductive point of view is that of experimental physics. No one will dispute that mathematical physics is based upon experimental physics. I suggest that, for our purpose, we may distinguish three levels of physics. There is first a study of the qualitative aspects of sensible

[1] Quoted from an article in *The Times*; see my *Modern Introduction to Logic*, p. 310.

[2] Cf. the following illuminating statement, made in *Relativity Theory of Protons and Electrons*, 0·2: 'All that we require from observation is evidence of identification that the entities denoted by certain symbols in the mathematics are those which the experimental physicist recognizes under the names "proton" and "electron". Being satisfied on this point, it should be possible to judge whether the mathematical treatment and solutions are correct, without turning up the answer in the book of nature. My task is to show that our theoretical resources are sufficient and our methods powerful enough to calculate the constants exactly—so that the observational test will be the same kind of perfunctory verification that we apply sometimes to theorems in geometry.'

experience with a view to discovering recurrences in sensory experience. At this stage it is noticed that hot bodies become cold, that a magnet attracts iron, that a moving billiard ball hitting another billiard ball causes the second to move, that a swinging lamp comes to rest, and so on. Statements in terms of qualities would not nowadays be recognized as having any place in physics. Indeed 'qualitative physics' may well seem to be a contradiction in terms. Nevertheless, physics has developed out of the discovery of such qualitative uniformities. The second level is reached when certain qualities are further abstracted and are correlated with numbers. The experimental physicist is concerned to establish precise quantitative laws describing the behaviour of bodies. Certain quantities are taken to be fundamental, and others are defined in terms of these. It is a matter of the historical development of physics that the fundamental quantities were at first defined independently of each other; subsequently experimental laws connecting them were discovered and came to be used as implicit definitions of the terms entering into them. For example, Archimedes defined "force" in terms of the weight of a body. Newton seems to have taken "force" as an undefined notion, recognizable in experience. After Newton had constructed his dynamical system based upon the three Laws of Motion, it was possible to regard the 'Laws' as themselves providing definitions of the fundamental dynamical terms.[1] By an analogous process of development the second law of thermodynamics can now be regarded as providing a definition of temperature.

It is now clear that Newton's Laws of Motion not only go beyond what is observed, or observable, but also include

[1] See C. D. Broad: *Scientific Thought*, p. 167.

in their statement terms that do not admit of precise definition. It is not in principle possible to observe a body 'subject to no forces'. This being so, it might seem surprising that the Laws of Motion should have been so successful in their application to the physical world. The reason for their success is that the undefinable terms *at rest* and *force* were not required for the purposes of calculation. They may be admitted to be the metaphorical elements that enabled Newton to formulate the laws in a manner intelligible to himself and his contemporaries, and thus helpful in the development of the physical sciences. Every one now recognizes that the Laws combine observation with convention, but at the time of Newton no element of convention was recognized. Restricting ourselves, for a moment, to a pre-Einsteinian mode of statement, we may say that the Laws of Motion are Laws of Nature in the sense in which we have distinguished these from natural laws.

To the extent to which the fundamental quantities of physics are all defined by implicit definitions, in the manner indicated above, it is possible to regard theoretical physics as a closed system, and as thus providing an example of the cyclic method. At this stage, the physical quantities concerned can be regarded as *so defined* that a violation of the field laws would be 'unthinkable', since these laws would be logical consequences of the definitions. This is what Eddington means by saying that these Laws are truisms. His claim is so important and, in my opinion, so unjustified in the sense required for his purpose, that it would be well to consider exactly what he says:

> Energy momentum and stress, which we have identified with the ten principal curvatures of the world, are the subject of the famous laws of conservation of energy and momentum. Granting that the

identification is correct, *these laws are mathematical identities.* Violation of them is unthinkable.

The vital point is contained in the phrase preceding the statement italicized by Eddington; this is—'*granting that the identification is correct*'. But in granting this, the controlling law, which Eddington has been so anxious to expel, is simply assumed. There is nothing logical in making this identification.[1] The appearance of deducing these physical laws from pure mathematics is the result of a trick. In short, Eddington's world-building is a construction of a general deductive system, i.e. it is a mathematical structure. When, and only when, the terms in the mathematical identities thus obtained are identified with electric and magnetic quantities, can the identities be regarded as Maxwell's equations. In assuming that the physical quantities are connected by the differential equations, the 'controlling law' has been assumed. The justification for making the identification is that the electromagnetic equations are true as a matter of experimental fact. This has nothing to do with logic.

Why does Eddington wish to deny this? There can be no doubt that he does so because he wishes to stress the part played by mind. In one of his earliest popular writings he concluded his survey of 'The Nature of Things' with the remark:

> All through the physical world runs that unknown content, which must surely be the stuff of our consciousness. Here is a hint of aspects deep within the world of physics, and yet unattainable by the methods of physics. And, moreover, we have found that where science has progressed the farthest, the mind has but regained from nature that which the mind has put into Nature.
>
> We have found a strange foot-print on the shores of the unknown.

[1] See the footnote on p. 79.

We have devised profound theories, one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the footprint. And lo ! it is our own.[1]

His successive incursions into metaphysics have always told the same tale. There are, indeed, three lines of thought that lead Eddington to his idealistic metaphysics. First, his theory of world-building; secondly, his belief that physics is wholly concerned with a schedule of pointer readings, cyclically interlocked, and such that through each term there runs an 'inscrutable nature', thirdly, his belief that the world of physics is symbolic of this inscrutable background as well as of the familiar world. In accordance with the first line of thought Eddington thinks of the physical world as standing in need of a builder. It is true that he does not put it quite in this way, but it is implicit in his conception of 'building' as similar to 'building constellations out of stars'. This is a selective activity. 'What we have called building', he says, 'is rather a selection from the patterns that weave themselves.' The use of the word "building" for the selective activity of singling out certain stars to form a pattern—such as the pattern formed by singling out the stars forming the constellation Draco—is an unfortunate metaphor. Its metaphorical character is obvious; it is unfortunate because it is apt to mislead the reader and has certainly misled its author. Perhaps it is not possible to say whether the extensive use of this metaphor is responsible for the welter of confusion which we are now about to examine, or whether the metaphor seemed appropriate only because the confusions its use engenders were already present to his thought.

The unmetaphorical use of the word 'building' is, as Eddington himself has pointed out, 'shifting about material';

[1] *Space, Time, and Gravitation*, pp. 200–1. Cf. below, p. 279.

no doubt we should add, 'according to a plan'. The builder, in Eddington's metaphor, is the mind; its building is an activity of selection. 'The things which we might have built but did not', he says, 'are there just as much as those we did build'(241). The scientific world (called also 'the world of physics') is built up by the mind. This statement cannot be interpreted as being merely an inept way of saying that *physics* is the work of men. What Eddington calls the scientific world contains electromagnetic waves, electrons, and stars. I do not think that Eddington wishes to say that men make, or build, the *stars*, but that the mind builds the *world of physics* in which stars are counterparts. Whether this interpretation of his view is correct or not must be discussed in the next chapter. What is clear is that Eddington believes that the mind builds *two worlds*: the familiar world and the scientific world. In this chapter we are concerned only with the latter. Of this world Eddington says: 'The simpler elements of the scientific world have no immediate counterparts in everyday experience; we use them to build things which have counterparts' (239). Examples of these counterparts are energy, momentum, stress; these are said to 'shadow well-known features of the familiar world'. These are *selected*. 'Ultimately', he says, 'it is the mind that decides what is lumber—which part of our building will shadow the things of common experience, and which has no such counterpart' (235). This is on one side misleading, on the other side nonsense. Certainly, if there is any deciding to be done, the mind *decides*, for only a mind can decide. Now, it is undoubtedly true that there are 'elements' in the 'scientific world' that have no familiar counterparts. I shall call them *constructs*. Their function, in my opinion, is to help us in the correlation of experience, i.e. in the ordering of what is sensibly experi-

enced. Hamiltonian functions, potentials, the aether, are examples of such constructs. These constructs are used by physicists in formulating what I have elsewhere called a constructive description. We can certainly say that Hamiltonian functions are the work of men ; the same can be said of the luminiferous aether. The use of the construct —the luminiferous aether—was in its providing a convenient way of saying that the path of a beam of light through empty space could be determined by means of a mathematical formula of the same kind as could be used for determining a wave of compression through a jelly. The luminiferous aether, if I understand the situation aright, has had its day, and may now be considered to be mere 'lumber'. Perhaps it is not incorrect to say that scientists *decided* to construct the luminiferous aether, although I think this mode of speaking suggests an explicit choice on their part which can hardly be regarded as offering an accurate account of the way in which nineteenth-century physicists did in fact think. But when Eddington says 'the *mind* decides', the common reader is likely to attach quite a different significance to the statement. Eddington himself does so. *The mind decides* is gradually transformed into *the mind contributes*, and then into, *the mind creates*. This transformation is all important for his metaphysics, and is utterly unwarranted.

In deciding to select this or that, it is presupposed that that which is decided upon, i.e. chosen, has some property in virtue of which it is *choosable*. What is *choosable*, and then *chosen*, depends both upon what the choice is to subserve and upon the entity chosen having the property required for the purpose that initiated the choice. If the mind seeks to construct an imitation of the commonplace world, it must choose that which is suitable for the purpose of the construction. The conservation laws have certainly been

found useful in the development of the physical sciences. The acceptance of these laws guided scientists in their search for quantities conforming to them. These quantities are, in the case of mechanical systems, functions of the masses, positions, and velocities of the particles ; in electrodynamical systems they are functions of the current strength and the potential difference. At this stage of the development of physics we can truly say that these conservation laws are *conventions*. In saying that these laws can now be regarded as conventions we are saying that experimental facts will now be so interpreted as to be consistent with them. In short, these ' laws ' are now recognized as guiding principles ; what were first taken to be *laws* concerning the behaviour of bodies came afterwards to be recognized as useful conventions. But these indisputable facts about the so-called laws of conservation do not, I think, justify the use that Eddington makes of them. ' The law of conservation ', he says, ' is a truism for the things which satisfy it ; but its prominence in the scheme of law of the physical world is due to the mind having demanded permanence. We might have built things which do not satisfy this law ' (241). Now it is true that *we* (i.e. scientists) might have built things which do not satisfy the law of conservation. Indeed Eddington immediately goes on to say that ' we do build one very important thing, " action ", which is not permanent '. It is true, again, that conservation laws are prominent in the scheme of physical laws, i.e. play an important part in the constructive descriptions of the physicist. But it is a fact about the natural world that it *can* be so ordered that conservation laws apply to it. That this is so is in no way due to the mind. Hence, there is no warrant for Eddington's conclusion that ' the element of permanence in the physical world ' is ' a contribution of the mind to the

plan of building or selection ' *unless* this statement be simply meant to assert that the conservation laws are guiding principles in physical *science*. If this is all that be meant, then Eddington has expressed himself in a misleading way, and has apparently misled himself into drawing conclusions about the part played by mind in science and in reality, which do not in fact follow. If more than this be meant, then, so far as I can see, Eddington has offered no reasons in support of his contentions. The difficulty of knowing which of these alternatives is correct is due to the difficulty of knowing exactly how Eddington uses the phrase ' physical world ' in the statement we have been discussing.

An examination of one of his illustrations may help to decide this point. He asks the question : ' Is the ocean composed of water or of waves or of both ? ' [1] He says that some of his ' fellow-passengers on the Atlantic were emphatically of the opinion that it is composed of waves '. No doubt the answer is amusing, but the question, taken strictly, has no sense. For, in the sense in which the ocean may be said to be ' composed of ' waves, it cannot be said to be ' composed of ' water. We know, Eddington says elsewhere,[2] that ' the progress of a wave is not a progress of any material mass of water, but of a form which travels over the surface as the water heaves up and down ; again the progress of a wave-group is not the progress of a wave. These forms have a certain degree of permanence amid the shifting particles of water '. All this is indisputable. How does it show that *permanence* is a contribution of the mind ?

[1] *N.P.Sc.* 319, and see also *N.Ph.W.* 242.

[2] In his chapter on ' World-Building '. Presumably the passenger's feeling that the ocean is composed of waves is due to his ' innate hunger for permanence '. I should not have thought that his experience satisfied this hunger.

What is 'the physical world' *to* which this contribution is supposed to be made? I think the context shows that here Eddington must mean what is often also called 'Nature', i.e. the world of natural events. It is to be contrasted with what he calls 'the scientific world', i.e. with what might be more appropriately described as 'the physical scheme'. The ocean is part of the physical world, i.e. of Nature. The waves in the ocean are discernible by sight; they are *waves in water*. The ocean is not 'composed of' waves in the same sense as it is 'composed of' water. There are not three things *ocean*, *water*, *waves*, so related that it would make sense to ask, as Eddington asks, 'Is the ocean composed of water or of waves or of both?' It makes sense to say that *lemonade* is composed of *lemon-juice*, *water*, and *sugar*. To say this is equivalent to saying that lemon-juice, water, and sugar are the ingredients which, mixed together, *make* lemonade. It makes sense to say that *water* is composed of *oxygen* and *hydrogen*, although this is a different usage of "composed of" from the usage in the statement about lemonade. That the usage is different can, I think, be seen if we remember that neither oxygen nor hydrogen is an entity completely isolated in the physical world apart from the investigations of experimentalists. We start from water and can by chemical analysis isolate oxygen and hydrogen. We start from oxygen and hydrogen, *thus isolated*, and can combine them into water by means of firing the mixture of the two gases with an electric spark. In this way, a good meaning can be assigned to the word "composed" in the statement that 'water is composed of oxygen and hydrogen'. But what meaning can be assigned to 'the ocean is composed of water'? "The ocean" is a name for a portion of the water that covers the surface of the earth. There is no more sense in asking whether the ocean is com-

posed of water than there would be in asking whether the king of England is composed of *man*. If now we ask, ' Is the ocean composed of waves ? ' we are asking ' Is a certain portion of water, designated as " the ocean ", composed of waves ? ' To this, it seems to me, the correct answer is that the question involves a misuse, or at best a wildly Pickwickian use, of " composed of ". The waves *of* the ocean are water-waves. It is true that the uneducated man may think that the *wave* is *something that travels over* the surface of the water. It is not difficult to make him see his mistake.[1] We can then understand that, as Eddington puts it, ' we can have waves of water, of air, of aether, and (in quantum theory) waves of probability ' (*N.P.Sc.* 320). Does Eddington suppose it would make sense to ask, ' Is an electron composed of waves or of probability, or of both ? ' Clearly he could not. The words " composed of " in such a combination do not yield a sentence that makes sense. It is true that Eddington does not ask this question, and therefore does not suggest that it would make sense. But the question he does ask is no less absurd. His purpose in reminding the reader that there are these various *waves* is to show him that ' a wave is a conception hollow enough to hold anything ', and he concludes : ' So after physics has shown us the waves, we have still to determine the content of the waves by some other avenue of knowledge.' [2] But it is not *physics*, nor even a physicist, that *shows* us the waves of the ocean. The passenger on the ship *sees* the waves ; he

[1] Eddington, as we have seen, does speak of ' a form which travels over the surface as the water heaves up and down ', but this is either a slip or one of the passages in which he is not ' saying what he means ', since *a form* is not *a thing which travels*.

[2] See below, p. 120, for Eddington's purpose in putting the problem in this way.

feels the water heaving up and down. All that the physicist does is to correct the passenger's misapprehension that the wave is *a thing that travels* or that breaks upon the shore. It is just as true that the world contains ocean-waves as that it contains stagnant ponds and water-weeds. But the water-weeds can be taken away from the pond ; the wave can no more be taken from the water than the grin from the cat. Nevertheless, we *see* the waves in the ocean.

To this Eddington would surely reply that I must be speaking about the familiar world. Certainly I am. But so, too, is Eddington when he speaks of the passengers on board ship who believe that the ocean is composed of waves. I think his discussion of this illustration shows that he is using " physical world " and " external world " as synonyms, and further, that the external world is that with which ' we can become acquainted through sensory experience ' (*N.P.Sc.* 319). If so, then he is saying that the mind contributes permanence to the physical world, i.e. to Nature, and not merely that the mind contributes permanence to the physical scheme, i.e. that the mind selects from Nature those properties that are conformable to the conservation laws. It is the latter that is true ; it is the former that is required to enable Eddington to draw his metaphysical conclusions.

That this is so may be seen from noticing the three points which Eddington desires to stress as the outcome of his World-building. These are : (1) that ' a strictly quantitative science can arise from a purely qualitative basis ' ; (2) that the laws hitherto regarded as the most typical natural laws are of the nature of truisms ; (3) that by its selective activity the mind has ' fitted the processes of Nature into a frame of law of a pattern largely of its own choosing ; and in the discovery of this system of law the mind may

be regarded as regaining from Nature that which the mind has put into Nature ' (*N.Ph.W.* 243–4). The third point is crucial. Let it be granted that the physicist[1] ' fits Nature to a pattern of his own choosing '. This may be taken to mean that the physicist's constructive description is attained by his attending to certain properties of what there is in Nature, by constructing hypothetical entities (i.e. constructs) whose function is to aid in the correlation of what is sensibly observed, and by using whatever mathematical methods may serve to develop the correlation ; he is thereby enabled to single out certain ' laws ' as guiding principles for further investigation. These laws will then be conventions which restrict the *future* interpretation of the experimental facts, unless they be rejected as inconvenient in the face of newly discovered experimental facts. In what sense can this system of law be said to be *discovered* ? In what senses of " put " and " Nature " can the physicist be said to *put* anything *into Nature* ?

I think the answer to the first of these two questions is that the system of law is not ' discovered ' in the same sense of " discovered " as that in which America can be said to have been discovered, nor in the sense in which the planet Neptune was discovered and in which no planet Vulcan has been discovered although it was confidently foretold. Science is in the minds of men. Natural occurrences obey laws in the sense of " law " which I described as ' natural laws ' and contrasted with ' Laws of Nature '. Such natural laws are discoverable in a straightforward sense. To the extent to which it is admitted that certain laws are *conventions*, they are not in the same sense *discovered.*

The second of the two questions does not, I think, make sense unless ' Nature ' be here used as a synonym for ' the

[1] The *physicist*, not *the mind.*

physical scheme', i.e. the system of scientific laws. In that case, this question is indistinguishable from the first. Eddington's belief both that the second question makes sense and is also distinguishable from the first supplies the answer to the question why he wishes to maintain that Maxwell's equations are mathematical identities and that, in the science of electro-magnetism, there are no controlling laws. For the same reason he wishes to maintain that the subject matter of physics is pointer-readings.

Eddington's view that 'the whole subject matter of exact science consists of pointer-readings and similar indications' has attracted much attention and has received a good deal of criticism. It is fundamental to his philosophy of science and to his metaphysical conclusions. His example of the substitution of pointer-readings for an elephant, by a candidate in an examination in mechanics, may seem to be so famous as not to need to be quoted in yet another discussion of his view. But the points raised in this example show so admirably what Eddington's position is that the example must be considered in detail. He says:

> If we search the examination papers in physics and natural philosophy for the more intelligible questions we may come across one beginning something like this: "An elephant slides down a grassy hillside . . ." The experienced candidate knows that he need not pay much attention to this; it is only put in to give an impression of realism. He reads on: "The mass of the elephant is two tons." Now we are getting down to business; the elephant fades out of the problem and a mass of two tons takes its place. What exactly is this two tons, the real subject matter of the problem? It refers to some property or condition which we vaguely describe as "ponderosity" occurring in a particular region of the external world. But we shall not get much further that way; the nature of the external world is inscrutable, and we shall only plunge into a quagmire of indescribables. Never mind what two tons *refers* to; what *is* it? How has it actually entered in so definite a way into our experience? Two tons *is* the

reading of the pointer when the elephant was placed on a weighing-machine. Let us pass on. "The slope of the hill is 60°." Now the hillside fades out of the problem and an angle of 60° takes its place. What is 60°? There is no need to struggle with mystical conceptions of direction; 60° is the reading of a plumb line against the divisions of a protractor. Similarly for the other data of the problem. The softly yielding turf on which the elephant slid is replaced by a co-efficient of friction, which though perhaps not directly a pointer reading is of kindred nature. . . .

And so we see that the poetry fades out of the problem, and by the time the serious application of exact science begins we are left with only pointer readings. If then only pointer readings or their equivalents are put into the machine of scientific calculation, how can we grind out anything but pointer readings? But that is just what we do grind out. The question presumably was to find the time of descent of the elephant, and the answer is a pointer reading on the seconds' dial of our watch (*N.Ph.W.* 251–2).

This passage seems to me to be singularly perverse. Of course it is amusing, for Eddington never fails to entertain his audience (or his readers). But it is perverse because the essential point is slipped in only at the end, and prefaced by a 'presumably' which is certainly misleading: 'The question presumably was to find the time of descent of the elephant.' There is no 'presumably' about the question. The answer is a definite number of seconds, i.e. the answer is metrical in character. But, since the problem is to determine *the time of descent*, it follows that the only relevant aspects of the elephant's adventure are also metrical. The scientist in order to solve the problem must pay attention only to the data that will be of use to him in solving it. He seeks a precise answer to a precise question. He must accordingly isolate certain aspects, i.e. abstract them from the situation as a whole. He is immensely helped by the work of previous scientists and can thus substitute for the complicated situation, *elephant-sliding-down-a-hill*, a much

more simplified situation in which the only relevant aspects are a mass and a frictional slope. But the problem is a problem about the time of descent of the *elephant*. The examinee has to pass back to the situation containing the elephant and the hill, and to attribute to it the characteristics which he has discovered by considering the simplified situation. This return process Eddington completely ignores. Indeed, he attempts to forestall such an objection. He says :

> The problem necessarily involves some kind of connecting background. It was not the pointer reading of the weighing-machine that slid down the hill. And yet from the point of view of exact science the thing that really did descend the hill can only be described as a bundle of pointer readings. (It should be remembered that the hill also has been replaced by pointer readings, and the sliding down is no longer an active adventure but a functional relation of space and time measures.) The word elephant calls up a certain association of mental impressions, but it is clear that mental impressions as such cannot be the subject handled in the physical problem.

I venture to suggest that these statements are as nonsensical as they sound, and that Eddington has been led to make them only because he has not asked himself the question : ' What exactly is a pointer-reading ? ' The nearest approach to an answer to the question what is meant by the *word* " pointer-reading ", that Eddington gives, is contained in the statement : ' The observation of approximate coincidence of the pointer with a scale-division can generally be extended to include the observation of any kind of coincidence—or, as it is usually expressed in the language of the general relativity theory, an intersection of world-lines ' (253). Intersections of world-lines are surely *events*. Again, the elephant is said to be ' a bundle of pointer-readings ' (256), and surely this must be interpreted as a bundle of *events*. Again, he says : ' Whenever we state the properties

of a body in terms of physical quantities we are imparting knowledge as to the response of various metrical indicators to its presence, *and nothing more* ' (257). Are not these responses to the presence of a body *events* ? I think that Eddington must be interpreted as meaning that statements concerning ' the properties of a body in terms of physical quantities ' are to be regarded as analysable into statements about events. Such an interpretation might enable us to make sense of the remark that ' a bundle of pointer-readings descended the hill ', which, as it stands, is absurd. However, it is not likely that Eddington would admit the correctness of such an interpretation since he regards his view as different from the view associated with Whitehead's use of the method of extensive abstraction although not in contradiction to it.

There are other passages in which it seems clear that Eddington thinks of pointer-readings as signs, or symbols, or marks on a scale. Pointer-readings are said to ' describe ', or to be a description. Again, ' two tons *is* the reading of the pointer when the elephant is placed on the weighing-machine '. Moreover, science is said to be wholly concerned with *symbols*, and the subject matter of science is said to be pointer-readings. But if we interpret pointer-readings as symbols, then it does not make sense to say that pointer-readings *are* intersections of world lines, nor that bundles of them *descend* hills. Consequently, it seems to me that the most consistent view for Eddington to adopt is that pointer-readings are events. It must, however, be admitted that much that he says forbids such an interpretation.

In studying Eddington's account of the elephant's adventures, in which the ' active adventure ' of sliding down is replaced by ' a functional relation of space and time measures ', I am once again led to wish that he had given us a definite

account of his theory of physical measurement. When he says that 'the physicist's knowledge *bears* upon the knowledge of matter but it *is* a knowledge of pointer-readings only', he seems to be forgetting the way in which physical measurements are obtained and the way in which they can be used for the purpose of predicting what will happen. It can hardly be Eddington's intention to maintain that pointer-readings are the primary data of physics in the sense that the science of physics could be said to have originated in the study of pointer-readings. Indeed, he admits that we could not tackle 'the problem of the elephant's escapade *ab initio* as though it were the first inquiry we had ever made into the phenomena of the external world'. He stresses the fact that the examiner would have had to provide more data 'if he had not presumed a general acquaintance with the elementary laws of physics, i.e. laws which permit us to deduce the readings of other indicators from the reading of one'. But he immediately adds: '*It is this connectivity of pointer-readings, expressed by physical laws, which supplies the continuous background that any realistic problem demands.*'[1] Elsewhere he says that the pointer-readings are the beginning, and that they 'constitute the material which contains all the recurrences whereby the cryptogram is deciphered' (*N.P.Sc.* 15). This is a baffling statement. How are we to interpret "material" and "contains"? It seems that the recurrences in sensory experience are recurrent signs, and that pointer-readings *contain* these recurrences. Surely this must be taken as suggesting that pointer-readings are indicative of qualities (of the sort called 'secondary qualities') that must be apprehended by the physicist in the process of discovering the physical laws which 'express the connectivity of pointer-

[1] Italics his.

readings'. He evidently seeks to establish a complete divorce between physical *theory* and *its application.* Physical theory has for its subject matter nothing but pointer-readings; yet it *bears* upon something that is not pointer-readings. Such a divorce appears to me to be quite untenable, and indeed, nonsensical. It is not possible to develop a *theory of measurement* on the basis of a complete severance of theory from its application. Physical measurement is logically dependent upon the observation of sense-data. A measurement states a relation between what is measured and the instrument of measurement. An instrument of measurement is a physical entity. A physical theory is concerned with the observable relations in which perceivable entities stand to one another. If the theory be completely severed from application to the observable entities, then mathematical physics is replaced by mathematics.

This criticism is similar to the criticism I have already made of Eddington's game of World-building. It is in like manner applicable to his conception of the cyclic method. A physical theory must have a physical meaning. Physical knowledge cannot be confined to pointer-readings; it is at least knowledge about the order of sensory recurrences.

Chapter V

THE DESCENT TO THE INSCRUTABLE

> 'facilis descensus Averno ;
> Noctes atque dies patet atri janua Ditis :
> Sed revocare gradum, superasque evadere ad auras,
> Hoc opus, hic labor est.'
>
> VIRGIL

HAVING left himself with a scientific world composed of pointer-readings and nothing more, Eddington feels the necessity of finding some 'background' in which the pointer-readings may be 'embedded'. At this stage of his inquiry Eddington's statements seem to me to be almost inextricably confused. In a chapter in the *New Pathways of Science*, in which he was replying to some of the criticisms passed upon his earlier writings, Eddington complained that his 'shallower critics' failed to see that he approaches 'the many-sidedness of truth' from different angles. Consequently, these critics accused him of inconsistency when they should merely have noted that he was making different approaches to 'the truth'. He adds: 'The shallower critics have also made capital by mixing passages in which the outlook is purely scientific, or passages in which I was leading the reader on, with those giving explicit statements of my philosophical ideas.' In defence of these critics (and, therefore, of myself) it must be urged that Eddington does not afford his readers much help in distinguishing his

various approaches. It is difficult for the common reader to keep his head amidst the bewildering multiplication of 'worlds', 'schemes', and 'systems'. Some attempt must be made to sort out the following notions: the familiar world, the external world, the scientific world, the physical world, Nature, the world of physics, the spiritual world. We have to try to find out what each of these denotes; we shall want to know why there are so many 'worlds', how they are mutually related, and what is the significance of the expression "a *world*". It must be confessed that, since Eddington gives us very little guidance in sorting out these various 'worlds', our inquiries may not meet with success. This is regrettable, for, to the extent to which we fail in this investigation to that extent at least we must fail to understand Eddington's philosophy of Nature.

We have already met the expression "the familiar world". I think that there can be no doubt that Eddington means us to understand by this what any common reader would regard as the world we inhabit, which contains the furniture of the earth and is the scene of our daily activities. Eddington has sometimes described the familiar world as 'a world of familiar acquaintance in human consciousness'. In Chapter III we considered his account of the familiar table and of its relation to another table called 'the scientific table', assigned by Eddington to a 'world of shadows'. He has a later variation of this account, in which he contrasts, not two *worlds*, but two *stories*—the familiar story and the scientific story. 'The perceiving part of my mind', he says, 'tells me a story of a world around me. The story tells of familiar objects. It tells of colours, sounds, scents belonging to these objects; of boundless space in which they have their existence, and of an ever-rolling stream of time bringing change and incident. It tells of other life

than mine busy about its own purposes' (*N.P.Sc.* 1). This familiar story is said to have 'some foundation of truth', and at one stage in the development of science the scientific story and the familiar story did not widely diverge. But of late their divergence has become so extreme that 'it has become hard to recognize that they have anything in common'.

The contrast between two *stories* is much easier to understand than the contrast between two *tables* or two *worlds*. It suggests at least that they are two versions of the *same world*, whatever may be the appropriate adjective to prefix to 'world' in this statement. If the fact that there are two divergent stories of the same world should give rise to a problem, it would surely be possible to solve the problem by considering the divergence in the starting-points of the two story-tellers and by contrasting their respective aims. Eddington is insistent that there is such a problem; I do not think, however, that he would welcome so short a way out of it. Indeed it seems to be his deliberate intention to make a mystery where, perhaps, there is only a need for correlation. Or does he desire only to mystify his audience, or, perhaps, to delight them with nursery talk? Certainly he seems always to regard his audience as composed of very childish persons, incapable of listening to any straightforward statement but ready to be charmed with parables and fancies. But he finds it difficult to keep within the limits of the fanciful parable of the moment. Or does he seriously mean to suggest that 'the *perceiving* part of my mind' tells me of 'boundless space' and of 'an ever-rolling stream of time'?

Questions such as those suggested in the preceding paragraph are likely, I think, to occur to any serious common reader who tries to understand what Eddington *means*, which, he has warned us, is not always exactly what he *says*.

I am doubtful whether any reader would be able to answer such questions. Eddington is pre-eminently a scientist. His command of the nursery language seems insufficient to keep him from falling into odd confusions and from mixing up his use of personal pronouns in a manner that would surely be perplexing to any intelligent childish listener. Consider the following passage :

> I will assume that you agree that the only channel of communication between the story teller who lives in your mind and the external world which his story professes to describe is the nervous system in your body. In so far as your familiar conception or picture of what is going on around you is founded on your sense of sight, it depends on impulses transmitted along the optic nerves which connect the retina with the brain. Similarly for your other sense organs. You do not, of course, perceive the impulses themselves ; the story teller has worked them up into a vivid story. (*N.P.Sc.* 3.)

I can imagine that the childish listener might ask : Why can't *I* tell the story ? Why do I need a story-teller living in *my* mind ? Is my mind a little house ? Why does the story-teller ' profess to describe ' the external world, but ' works up ' instead a vivid story ? No doubt these questions are absurd. But is the childish listener who asks them being very unintelligent ? I hardly think so. Eddington's use of the two different personal pronouns—*you* and *he*—inevitably gives rise to them. But when, in the beginning of the parable, he spoke in the first person singular he made it clear that the story-teller is ' the perceiving part of my mind '. The perceiving part of my mind is, I think, regarded by Eddington as the inside of my head. My head is regarded as a windowless room with an ' ever-sealed door '. Again and again Eddington gives this illustration, or variations of it, and uses it not as an illustration but as an argument. ' We picture the mind ', he says, ' like an editor in his sanctum receiving through the nerves scrappy

messages from all over the outside world, and making a story of them with, I fear, a good deal of editorial invention' (*N.Ph.W.* 100). On a later occasion he was more explicit. I shall quote the passage in full, for it brings out very clearly what Eddington conceives to be the nature of the problem of our knowledge of the external world.

> The inside of your head must be rather like a newspaper office. It is connected with the outside world by nerves which play the part of telegraph wires. Messages from the outside world arrive in code along these wires; the whole substratum of fact is contained in these code messages. Within the office they are made up into a presentable story, partly by legitimate use of accumulated experience, but also with an admixture of journalistic imagination; and it is this free translation of the original messages that our consciousness becomes aware of.
>
> If we had a complete record of the impulses transmitted along the nerves we should have all the material which the story teller can have had as a foundation for his story—in so far as his story relates to the external world. And it is to this material that we must appeal if we wish to discover the truth behind the story. To appreciate the task of physical science let us then suppose that we are in possession of these data—the dots and dashes, or whatever the signals are, that arrive at the brain cells at the terminations of the nerves. All that physical science can assert about the external world must be inferable from these. If there is any part of our conception of the physical universe which cannot have come to us in the form of nerve signals we must cut it out. (*N.P.Sc.* 4.)

Eddington thus seems to regard the familiar world as a story constructed by the perceiving part of my mind out of messages received from the external world. But the messages *received* are a 'free translation' of that which was sent.[1] It is, indeed, only by courtesy that the *messages*

[1] Cf.: 'In fact, the mind has also invented a craft of world-building; its familiar world is built not from the distribution of relata and relations but by its own peculiar interpretation of the code messages transmitted along the nerves into its sanctum' (*N.Ph.W.* 240).

can be said to have been *received*, for I am conscious only of the free translation. He repeatedly emphasizes the point that the translation is a ' free translation '—so ' free ' indeed that it can hardly, one would suppose, be called a translation at all. ' The messages ', he says, ' as we become aware of them in consciousness are dressed up with conceptions of colour, spatiousness, substance. This dress is no part of the message as it was handed in by the external universe. It is assumed after the message arrives ; for the transmitting mechanism is by its very nature incapable of conveying such forms of conception.' The familiar world is an illusion ; it is an illusion that the perceiving part of the mind (i.e. the editor) makes for itself under the delusion that it is translating messages sent from the external world.

From this account it seems fairly clear that Eddington thinks of the external world as *that which sends the messages*. If he had elaborated his parable I suppose he would have said that the objects in the external world correspond to the reporters who are responsible for sending messages along the wires. But the illustration must not be pressed. For, the editor in ' the newspaper office ' does not in the least know what the reporters are like ; he receives messages, not written in their handwriting, and he does not know at all what the messages are about. He dresses up the messages, but the ' dress is no part of the message as it was handed in by the external universe ', i.e. by the reporters. Moreover, the editor is not aware of the message until *after* it has been dressed up. So far as the editor is concerned the reporters are an inference ; they are inferred to account for the sending of the messages. If the parable is to be at all appropriate, we must add that the editor does not *know* that he is an editor, nor that he is dressing up messages, nor that the reporters are only inferred to account for the

undressed messages. For *the editor* in the parable corresponds to *the perceiving part of my mind.* It is Eddington who has discovered the editor ; it is *Eddington* who says to *me* (a common reader) : ' You do not, of course, perceive the impulses themselves ; the story teller has worked them up into a vivid story. The inside of your head must be rather like a newspaper office.' It is *Eddington* who tells *me* that the only channel of communication between the story-teller who lives in my mind and the external world which the story-teller professes to describe is the nervous system in my body. We shall have to inquire how Eddington knows all this. It is a little surprising that he should, for Eddington also is a man in whose mind dwells a story-teller. Only it happens that Eddington has managed to get the better of the story-teller and to put him down as a spreader of unwarranted rumours.

It may be objected that it is inept to criticize an illustration in detail, and that if a writer enlivens his discourse with a parable we should take it for what it is. In his *Autobiography* G. K. Chesterton complains of the people who ' cannot believe that anything decorated by an incidental joke is sensible ', and he professes that he has never understood ' why a solid argument is any less solid because you make the illustrations as entertaining as you can '. I agree with Chesterton. But I do not think that this line of defence is open to Eddington. His parable, or illustration, is not incidental but fundamental to his line of argument. His theory of our knowledge of the external world is based upon the assumption that ' mind is the first and most direct thing in our experience ; all else is remote inference '.[1] Whenever he attempts to show how it is that we have

[1] *S.U.W.* 24 ; Cf. also *N.Ph.W.* 281 ; *N.P.Sc.*5, and see also pp. 280–8 for Eddington's reply to criticisms of this statement.

knowledge of the external world and that this knowledge is ' a remote inference ', he uses the parable of the decoded messages. But in stating the parable he includes the conclusions that he seeks to establish by means of the parable. The following passage brings out very clearly how closely interwoven is the argument with the illustration :

> It is necessary to keep reminding ourselves that all knowledge of our environment from which the world of physics is constructed, has entered in the form of messages transmitted along the nerves to the seat of consciousness. Obviously the messages travel in code. When messages relating to a table are travelling in the nerves, the nerve-disturbance does not in the least resemble either the external table that originates the mental impression or the conception of the table that arises in consciousness. In the central clearing station the incoming messages are sorted and decoded, partly by instinctive image-building inherited from the experience of our ancestors, partly by scientific comparison and reasoning. By this very indirect and hypothetical inference all our supposed acquaintance with and our theories of a world outside us have been built up. We are acquainted with an external world because its fibres run into our consciousness ; it is only our own ends of the fibres that we actually know ; from those ends we more or less successfully reconstruct the rest, as a palaeontologist reconstructs an extinct monster from its footprint (*N.Ph.W.* 277–8).

The first part of this statement is expressed in the parable language, but the parable is transformed into an argument. The process of decoding becomes a process of ' very indirect and hypothetical inference ' by means of which we have built up both our ' supposed acquaintance with ' and also our theories of the external world. What, presumably, is ' supposed ' is a world outside us with which we are acquainted, whereas, Eddington maintains, it is only our own ends of fibres running from the external world into our consciousness that we actually know. It is difficult to discover whether ' fibres ' is meant to be a metaphor, but

I am inclined to think that it is not so meant. If, however, it be meant as a metaphor, it is impossible to discover what the significance of the metaphor is. Since these 'ends of fibres' in our own consciousness are what we 'directly know', it ought not to be so difficult for us to discover what they are. But can it be plausibly maintained that *any* mind is acquainted with ends of fibres running into its consciousness? Can anyone recognize the description of his mind's self-knowledge as an awareness of receiving messages that have to be decoded? For my part, I must disclaim such self-knowledge.

Those who have such self-knowledge (Eddington thinks that every one has) are said to be able to reconstruct the rest of the fibres (or the external world?). The decoding process is compared with the process by which a palaeontologist reconstructs an extinct monster from its footprint. But this comparison is worse than unenlightening since it entirely misses the point. The mind cannot reconstruct; it must construct, if it does anything. Indeed, Eddington elsewhere always speaks of the external world as a construction, not a reconstruction. The palaeontologist, however, does reconstruct, and he is able to do so only because he has a considerable amount of knowledge of *other* entities that are of the *same sort* as that which he reconstructs. But the mind is said to have no knowledge at all of the source of the code or of the entities to which the code-messages refer. It may be questioned whether it makes sense to talk of a code for which there never has been a key, and which, moreover, is such that even if there had been a key, the code could have been translated only into a message that could not be understood.

This last remark needs some qualification in the light of a footnote that Eddington adds to the statement that 'the

nerve-disturbance does not in the least resemble either the external table that originates the mental impression or the conception of the table that arises in consciousness'. He adds that he means 'resemble in intrinsic nature'. He says that 'the symbolic description of structure will be identical for the table in the external world and for the conception of the table in consciousness if the conception is scientifically correct'. As it stands this seems almost to be a tautology; for, presumably, 'the symbolic description of structure' is the 'scientifically correct' conception. But it may be that Eddington means to say that there is similarity of structure between the table in the external world and the table in the mind (i.e. in the head). Nevertheless, a difficulty remains, for the decoding parable leaves it quite unexplained how it should be possible to compare the two tables so as to ascertain their structural similarity. The intrinsic nature of the external table is repeatedly said by Eddington to be inscrutable. Certainly he has done nothing to show how it is that the mind has ever been able to acquire the knowledge that there is a table at all. The only hint that he gives us is contained in the statement that 'that which the man himself knows as a succession of feelings is the reality which when probed by the appliances of an outside investigator affects their readings in such a way that it is identified as a configuration of brain-matter'. It must be admitted that even Eddington is seldom guilty of writing so confused and confusing a sentence as this. I suppose that 'the man himself' is my mind (or the mind of any common reader), and that Eddington is 'an outside investigator' who both knows how to use these probing instruments and is able to identify their readings as a configuration of brain-matter. It is left obscure whether this brain-matter is the mind, but if it is, then it is brain-matter that *knows* the

succession of feelings. The consideration of this difficulty must be postponed to the next chapter.

As a result of this long inquiry we have at least discovered that Eddington usually means by 'the external world' the source of the code-messages. The external world is *inferred* from our sensory experiences, although it is wholly unlike these experiences. I think that for Eddington the fundamental significance of the word "external" in the context "the external world" is that it emphasizes a world that is not dependent upon me either for its existence or for its characteristics. The external world is a world common to many percipients. He quotes, with evident approval, from Poincaré: 'What we call "objective reality" is, strictly speaking, that which is common to several thinking beings and might be common to all.' He says that 'our first intimation of externality' is not directly connected with physical science, but 'comes from the recognition that the problem of experience is concerned with data distributed among many different individual consciousnesses' (*N.P.Sc.* 10). These different experiences must be synthesized, and this synthesis 'necessarily leads to a neutral domain not co-extensive with any individual mind'. Clearly, then, the external world is neither logically nor epistemologically primitive. 'Although', he says, 'we start from individual mental data, as soon as we commit ourselves to the recognition of other minds than our own, we are led to the conception of an external domain (physical space and time) to contain the inferential objects of our combined knowledge.' Eddington cannot bring himself to disbelieve in the existence of other minds than his own—minds with whom he can communicate. Hence there is the need to construct an external world in which are located the sources of this communication. I do not think that Eddington

attempts to give any reasons at all for asserting that there are other minds. It may be objected that it is unreasonable to expect him to do so. Physics as a science results from the conjoint labour of many minds or persons. I agree. But Eddington, I think, is hardly entitled to assert this, for, as he insists, in accordance with his view of the nature of our knowledge of the external world, the inquiry concerning the nature of an other mind (called 'Mr. X') 'must take place in the domain of my own consciousness' (*N.Ph.W.* 268). I am not sure whether I am misrepresenting Eddington at this point. His interest is in the inquiry '*What is Mr. X?*' Our present concern is to know whether, in accordance with Eddington's views, there can be a Mr. X at all. But the difficulty is that Mr. X—indeed an army of Mr. X's—must be assumed if physics is to be possible. Yet, if I am to construct the external world, and if I must start from my own 'individual mental data', what warrant have I for supposing that there is in the external world any object at all resembling myself and worthy of being designated 'another mind'?

Eddington, I think, sees the difficulty but he slides away from it. Mr. X is required by him, so he seems to think, only in order to break through the cycle of physical definitions. He remains an inscrutability, not only as regards his nature but also as regards his being there—'wherever "there" may be'—at all. Accordingly, the consideration of Mr. X belongs to the next chapter.

With regard to the characteristics of the external world nothing can be said except that it contains entities capable of sending messages along the nerve fibres. These fibres, it will be remembered, are also in the external world, yet one end of each fibre is in consciousness. The message once sent, the mind does the rest; it constructs the familiar world.

This construction is, indeed, a veritable creation out of nothing. We construct our familiar world by interpreting in our own peculiar fashion the code messages from the external world. 'We' here stands for plain men, common readers, i.e. human beings engaged in the ordinary occupations of living. Our familiar world *seems* to be external because it *seems* to be shared with others. But that is a fairy tale, told by the story-teller who, if not exactly an idiot, is at any rate extremely credulous and incautious. 'The familiar world of my perception', says Eddington, 'seems to be external; but in the courts of science, what the familiar story-teller says is not evidence' (*N.P.Sc.* 9). I am not sure whether Eddington wishes to maintain that the external world is constructed by the physicists, or whether he only intends to say that the physicists can produce evidence that there is an external world, and that no one else can. Perhaps he wishes to maintain both. Anyhow, he admits that there is 'the external world which appears in the familiar story of perception' but urges that there is a gulf between it and 'the external world which presents its messages at the door of the mind'.

At this point we are brought up against the difficulty of discovering whether the external world is the physical world. It seems to me that the gravest difficulty attaches to the disentangling of Eddington's usages of the expressions "external world", "physical world", and "world of physics". Are these all used as synonyms? Or are the first two expressions synonymous but the third expression "world of physics" not a synonym? Nor are these the only expressions whose significance is difficult to determine. We encounter also the expressions "scientific world" and "physical reality", we also find Eddington talking about *Nature*, and we find it difficult to know which,

if any, of the foregoing expressions is a synonym for "Nature".

I wish to emphasize that I am not indulging in idle and profitless criticism of a careless usage of language. Nor am I forgetful of the difficulty of 'saying exactly what one means'. I am too conscious of having myself often been careless and slovenly in my usage of language to wish to make capital out of similar errors on the part of other people. Nor do I suppose that any fruitful criticism of a theory can be mainly based upon considerations concerning the carelessness with which it has been expressed. My criticism of Eddington is that he is confused in his thinking, and that, in consequence of this confusion, he uses many different expressions without himself knowing how far, if at all, they are used as synonyms.

A comparison of certain passages in which one or more of these expressions occur may suffice to show how difficult it is for the common reader to ascertain what precisely it is that Eddington is intending to assert.

> We have learnt that the exploration of the external world by the methods of physical science leads not to a concrete reality but to a shadow world of symbols, beneath which those methods are unadapted for penetrating. (*S.U.W.* 45.)

From this it seems clear that the physicist explores the external world, and that there results from the exploration 'a shadow world of symbols'.

> The external world of physics has thus become a world of shadows. (*N.Ph.W.* xvi.)
>
> The frank realization that physical science is concerned with a world of shadows is one of the most significant of recent advances. (*Ibid.* xvii.)

These statements surely suggest that the physicist *studies*

(i.e. 'is concerned with') a world of shadows, so that the external world is itself a shadowy world. But, if so, how are we to understand the next statement:

> Only let it be understood that the truth we seek in science is the truth about an external world propounded as the theme of study, and is not bound up with any opinion as to the status of that world. (*N.Ph.W.* 285.)

We cannot profitably discuss this statement unless we take into account the context within which Eddington makes it. But we may notice first that the external world is here asserted to be propounded as the theme of study for the physicist, and that he seeks to know the truth about the external world. On the next page Eddington says that the external world 'is the world that confronts that experience which we have in common'. These assertions are made in the course of his discussion of 'Reality'. He rightly insists upon the looseness of the words "reality" and "existence", and points out that 'the word "reality" is generally used *with the intention of evoking sentiment*'. Accordingly, as there is no way of knowing what would constitute a test of reality or existence, he refuses 'to contemplate the awful contingency that the external world, after all our care in arriving at it, might be disqualified by failing to exist'. This is a wise refusal. But, it seems to me, the difficulty remains of knowing whether Eddington is asserting that the external world is *arrived at*, as a result of the careful labours of the physicist, or whether the external world is *that from which the physicist starts*. I think that he makes both these assertions. Possibly he would deny that there is any distinction between them. But I, for my part, find it difficult to understand how the theme propounded for study can itself be the outcome of the labours of the physicists.

It may be possible to give a more sympathetic interpretation of Eddington's views. If so, a great deal of what he actually says must be neglected. It may, then, be granted that Eddington (or any physicist) somehow knows that there are many individual minds[1]; that each mind has its own private experience; that, nevertheless, communication between these different minds is possible, notwithstanding divergence in their view-points. The external world can then be regarded as that without which communication between different minds would be impossible. The business of the physicist is, then, to discover the nature of that in virtue of which communication is possible.

Even if such an interpretation of what Eddington means were, in part at least, correct, it still leaves unexplained how a world of shadows could be regarded as fulfilling the function of rendering possible communication between different minds. There is no need to press the metaphor (if Eddington intends it to be a metaphor) of a shadow-world. The difficulty is in no way lessened by the substitution of 'a scheme of symbols'. Consider the three following statements:

> The scientific world is, as I have often repeated, a shadow-world, shadowing a world familiar to our consciousness. (*N.Ph.W.* 109.)
>
> What we are dragging to light as the basis of all phenomena is a scheme of symbols connected by mathematical equations. This is

[1] See *N.Ph.W.* 283: 'You are able to communicate to me part of the content of your consciousness which thereby becomes accessible in my own. For reasons which are generally admitted, though I should not like to have to prove that they are conclusive, I grant your consciousness equal status with my own; and I use this second-hand part of my consciousness to "put myself in your place". Accordingly my subject of study becomes differentiated into the contents of many consciousnesses, each content constituting a *view-point*.'

what physical reality boils down to when probed by the methods which a physicist can apply. (*N.P.Sc.* 313.)

We recognize a spiritual world alongside the physical world. Experience—that is to say, the self *cum* environment—comprises more than can be embraced in the physical world, restricted as it is to a complex of metrical symbols. (*N.Ph.W.* 288.)

I shall assume that 'the scientific world' is a synonym for 'the world of physics'—an expression that, as we have seen, Eddington also uses. This assumption is in accordance with Eddington's belief that science is equivalent to physics. But it is more difficult to know whether he distinguishes between 'the scientific world' and 'the physical world', and if so, *how* he distinguishes between these two expressions. If they are to be distinguished, which of these expressions is to be used as a synonym for "Nature"? Or are there three non-synonymous expressions: "world of physics", "physical world", and "Nature"?

According to the statements quoted above, Eddington's view is that the physical world is a complex of metrical symbols, that these symbols 'shadow' the familiar world, but that experience comprises more than can be shadowed by a complex of metrical symbols. I assume that "physical reality"—an expression that occurs in the second of the three statements under discussion—is a synonym for "the physical world" as it is used in the last of the three statements. I do not think that the word "Nature" could be substituted for either of these expressions without making nonsense of Eddington's statements. In another connexion he himself speaks of 'a dynamic quality in external Nature',[1]

[1] *N.Ph.W.* 88. I think that in this passage Eddington is using the word "Nature" in the sense in which it is used by the common reader when he contrasts Nature with Spirit. Cf. the following anecdote, told (or retold) by Sir J. J. Thomson, of H. T. S. Smith, a

and I think it is clear that he is *not* there using "Nature" as a synonym for "the world of physics". I should myself regard the word "Nature" as a good word to use to indicate whatever is, or could be, sensibly experienced together with the occasions and conditions of what can be sensibly experienced and the modes of their interconnexions. I believe that 'the theme of study' that is 'propounded' to the physicist is Nature (thus understood) in certain of its aspects, namely, those aspects that are susceptible of mathematical treatment. If this be correct, then the physicist studies Nature in order to correlate happenings in Nature (i.e. natural events), whilst 'the world of physics' is the outcome of his labours. In accordance with this interpretation, Eddington ought to have said that it is the *world of physics* that is 'restricted to a complex of metrical symbols', not that the *physical world* is thus restricted, unless, indeed, he regards the two statements as equivalent. I do not think that Eddington's plea that he must use inexact language would be relevant at this point. The resources of English and his knowledge of its correct usages are surely sufficient to enable him to make clear how exactly he intends to use the expressions "physical world", "world of physics", "external world", "physical reality", and "Nature", and to explain whether any two or more of these expressions are synonymous. I believe, in fact, that he is fundamentally confused and that his metaphysical views are the outcome of these confusions.

famous Oxford Professor of Mathematics. He is recorded to have said of 'an editor of the scientific journal *Nature*, who was sometimes accused of being cocksure about many things', that 'X fails to recognize the difference between the Author and Editor of *Nature*' (*Recollections and Reflections*, p. 294). Everyone understands how "Nature" is used in the expression "the Author of Nature".

Whilst, then, it is to be hoped that every one would agree that 'the world of physics' does not comprize the whole of experience, I should myself regard this statement as tantamount to the recognition of the limitations of physical science. Eddington, however, seems unwilling to admit that his contention could be more suitably stated in terms of a restriction of the scope of physics rather than in terms of the mutual exclusiveness of two, or more, worlds. This is unfortunate. I cannot help thinking that Eddington is not himself clear with regard to what a symbol is, how it is that *we* can use symbols, and how it is that advance in the physical sciences goes along with advance in the construction and use of symbolic methods.[1] Accordingly, he fails to realize that 'the world of physics', i.e. the constructive descriptions of the physicists, is necessarily restricted in its reference to experience. This restriction is a logical consequence of the nature of the methods appropriate to the study called 'physics'; it is not an unfortunate result of the inscrutable nature of the world. On his own admission, the physicist starts from the familiar world of tables, stars, and eclipses, aims at constructing a complex of metrical symbols which shall symbolize the recurrences in this familiar world, and has found it necessary, in order to fulfil this aim, to introduce symbols that have no exact counterpart in sensible experience and thus cannot be translated into the language of common sense. The methods of physical science are not adequate, and are not intended to be adequate, to the description of all that is experienced.

Do not these considerations suggest the conclusion that physical science is concerned with one world, and with those aspects alone of what is sensibly perceived in it that

[1] This failure on Eddington's part has some queer consequences, as we shall see in Chapter VI.

are susceptible of metrical treatment? To put the point in this way would be to avoid the puzzling multiplication of 'worlds'—which have subsequently to be interlinked—and would also avoid the wholly baffling notion of a complex of metrical symbols as *shadowing* tables, stars, and eclipses. To put the point in this way is, however, not agreeable to Eddington. To conceive of the limitations of physical science as a restriction only of the scope of the science itself—a restriction necessitated by the aims of its research—would be to destroy the foundation of his metaphysic.

Eddington, then, in the interests of his metaphysic emphasizes the abstract nature of physical knowledge without, however, calling attention to the fact that it is *abstract*. On the contrary, he substitutes a *shadow* for a *symbol*, and then insists that physics is confined to studying a world of shadows. The subject matter of physics is not to be regarded as the domain of natural events but as schedules of pointer-readings. The shadowy nature of the schedules is emphasized in order to bring out the need for finding a 'background' in which the pointer-readings may be 'embedded'. The cyclic method is emphasized in order to introduce the need for breaking the cycle; the cycle is to be broken in order to reveal the inscrutable nature that has been asserted to run through the terms of the cycle. The multiplication of worlds, shadowing or symbolizing each other (it matters little which) is emphasized in order that these worlds may be finally interlinked by means of that which lies beyond physics. In short, it is essential to the development of Eddington's metaphysical views that he should be able to interpret the recent developments of physics as reminding us of 'the essential unknownness of the fundamental entities of physics'. We shall not be

content with an Unknown; consequently, we shall demand a 'supplement' to physics. So long, however, as we remain within 'the world of physics', we can adopt the words of Trinculo, for, says Eddington, 'Trinculo might have been referring to modern physics in the words, "This is the tune of our catch, played by the picture of Nobody".'

At this stage the descent to the inscrutable has been accomplished.

Chapter VI

CONSEQUENCES OF SCRUTINIZING THE INSCRUTABLE

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ALK'Q HKLT TEXQ.

THIS chapter should properly consist of a blank page. But I cannot resist the temptation to follow Eddington in his effort to penetrate into the inside of the newspaper office right into the editor's sanctum, or, alternatively, to unravel the mysteries of Broadcasting House. Moreover, an examination of the reasons leading Eddington to postulate inscrutable natures, a careful consideration of what he finds to say about these inscrutabilities, and a reconsideration of the abstractness of physics may enable us to avoid making the descent and thus having to accept the blank consequences.

Eddington is not alone in having been led, through his reflexions concerning recent developments in physics, to the discovery (if the word is permissible) of the inscrutable. We saw in Chapter II that Jeans also is convinced that there is 'a mysterious world outside ourselves to which our minds can never penetrate'. The agreement in their views, however, is not very profound. It might do more justice to Eddington to say that he is usually concerned to emphasize rather the mystical than the mysterious element in the universe, and that he seeks to do so by laying stress upon the significance of experience and upon the scientist's respect

for truth. He would not, I think, agree with Jeans that our *minds* are unable to penetrate to the ' mysterious world outside us '. In his opinion it is the physicist, using only the methods of physical science, who is thus disqualified. No reader of Eddington's philosophical writings, or of his Swarthmore lecture delivered to the Society of Friends, could be in doubt as to the strength and purity of his conviction that he has direct awareness of a spiritual reality. In view of the fact that this chapter is wholly critical it is desirable to remind the reader that Eddington has not attempted, and has never felt the need to attempt, to deduce religion from modern physics or to base religion on scientific discovery. Such an attempt would surely be utterly foreign to his outlook and incompatible with the profoundly mystical nature of his own religious experience. Numerous passages could be quoted from his writings in support of this statement. It will suffice to quote one :

> I now turn to the question, what must be put into the skeleton scheme of symbols. I have said that physical science stands aloof from this transmutation, and if I say anything positive on this side of the question it is not as a scientist that I claim to speak.[1]

Our concern is not with the transmutation but with the skeleton scheme of symbols—not with what is ' put into ' this skeleton but with the claim that physics needs any such supplementation.

It is important to notice that, according to Eddington, it is physics itself, as a science, that requires this supplementation. If he were right, then there must be a meta-physics, that is, a study ' beyond physics ' and yet a study that must be taken note of by the physicist himself. If this were so, then who could be more competent than the physicist to inform us of the results of this study ? Yet Eddington

[1] *Science and Religion : A Symposium*, p. 126.

takes care to tell us that ' physics stands aloof from this transmutation ', and that in speaking about what has to be ' put into the skeleton scheme of symbols ' he is not claiming to speak as a physicist. This seems to me a very odd position. I should have thought that the supplementation must be provided by a super-physicist and be as much a contribution to physics as the work of a super-mathematician (to use Eddington's expression) is a contribution to mathematics.[1] In short : either physics does stand in need of supplementation or it does not ; if it does, then the supplement must be provided by the physicist ; if it does not, then Eddington's meta-physics must be metaphysics, and must accordingly be judged as such.

In insisting upon the need for a supplement to physics, Eddington contrasts the attitude of contemporary physicists with those of the last century. ' The Victorian physicist ', he says, ' felt that he knew just what he was talking about when he used such terms as *matter* and *atoms*. Atoms were tiny billiard balls, a crisp statement that was supposed to tell you all about their nature in a way that could never be achieved for transcendental things like consciousness, or beauty or humour. But now we realize that science has nothing to say as to the intrinsic nature of the atom. The physical atom is, like everything else in physics, a schedule of pointer-readings ' (*N.Ph.W.* 259).

Eddington is justified, I think, in calling attention to a fundamental difference between the Victorian physicist and contemporary physicists. It is primarily a difference in attitude or outlook. The Victorian physicists (or at least some of them) were cocksure with regard to the ultimacy of their theories, with regard to the complete adequacy of the methods they were then employing, and with regard

[1] See *N.P.Sc.* 271.

to the *kind* of theories that would subsequently be discovered. In all these respects their cocksureness was as unwarranted as their contempt for metaphysics was unenlightened.[1] I think, too, that Eddington is right when he says that the Victorian physicists felt quite confident that they knew just what they were talking about when they used the words "matter" and "atoms".[2] Moreover, they ascribed to microscopic entities, e.g. atoms, properties that belong only to macroscopic bodies. Thus, for example, because a cricket ball is hard, and because it was thought to be composed of atoms—in a perfectly straightforward sense of 'composed of'—it was supposed that atoms also were hard. This we now know to be a mistake. It was, moreover, a mistake that had far-reaching consequences upon the philosophical views both of scientists and of philosophers who were interested in scientific theories. It can hardly be denied that these changes in the views of scientists, which have been brought about by the way in which the physical sciences have in fact developed, have interesting implications for philosophy. But to admit this is surely not to admit that whilst 'Victorian physics' did not require a supplement, contemporary physics does require one. Yet it is this that Eddington is concerned to maintain, and this is required for his metaphysical superstructure. 'The recognition', he says, 'that our knowledge of the objects treated in physics consists solely of readings of pointers and other indicators transforms our view of the status of physical knowledge in a fundamental way. Until recently it was taken for granted that we had knowledge of a much more intimate kind of the entities of the external world'

[1] Cf. my article on 'Abstraction and Science', *Journal of Philosophical Studies*, Jan. 1927.

[2] Cf below.

(*N.Ph.W.* 258). What exactly is the nature of this radical change in the physicist's view of the status of physical knowledge? We have seen that Eddington maintains that the subject matter of physics is confined to pointer-readings. If he wishes to maintain that the physicist begins and ends his study with pointer-readings, that the origin, data, and results of physical research are pointer-readings, then he could safely neglect to consider how pointer-readings are obtained, how they are in fact used, and how laws (which he says express the connectivity of pointer-readings) are tested. But in that case there seems no reason to call them 'pointer-readings'. The 'world of physics' would indeed be nothing but a 'complex of metrical symbols', and 'physical knowledge' would vanish since 'physics' would be indistinguishable from mathematics.

This is not, of course, Eddington's intention. In his very interesting chapter on 'The Theory of Groups' (*N.P.Sc.* Ch. XII), he tells us that he once worked out the structure of a certain group of operators in connexion with Dirac's theory of the electron, and that he afterwards learned that a great deal of what he had written was to be found in a treatise on Kummer's quartic surface. He adds that Kummer would have been surprised to know that he was dealing with the behaviour of an electron, whereas he himself had not supposed that he was writing a paper on the structure of Kummer's quartic surface. The story is instructive. Mathematical physics is not mathematics; nor is physical knowledge a knowledge of pointer-readings only.

Since Eddington does not believe that physics has become mathematics, we must look for another explanation of the transformation in the status of physical knowledge. The explanation is to be found in the fact that the Victorian physicist believed that he knew the intrinsic nature of the

atom, whereas Eddington who believes that the atom has an intrinsic nature believes also that this intrinsic nature is unknown. What the physicist knows of the atom is a schedule of pointer-readings. Accordingly he argues :

> There is always the triple correspondence :
> (*a*) a mental image, which is in our minds and not in the external world ;
> (*b*) some kind of counterpart in the external world, which is of inscrutable nature ;
> (*c*) a set of pointer-readings, which exact science can study and connect with other pointer-readings. (*N.Ph.W.* 254.)

In this triple correspondence (*a*) is the familiar world, (*c*) is the symbolic world of physics, (*b*) is the inscrutable which must somehow or other be invoked to supplement (*c*). ' A skeleton scheme of symbols ', protests Eddington, ' proclaims its own hollowness. It can be—nay it cries out to be —filled with something that shall transform it from skeleton into substance, from plan into execution, from symbols into an interpretation of the symbols ' (*N.P.Sc.* 314).

In his attempt to provide the supplement Eddington has, I think, two rather different lines of argument, the first of which is given in the *Nature of the Physical World*, the second mainly in *New Pathways in Science*. The difference is perchaps chiefly in emphasis and in terminology. They are both directed to showing that there are entities of which we have intimate, and not merely symbolic, knowledge.

The first line of argument depends upon the assumption that the schedule of pointer-readings must be ' attached to some unknown background '. It might well seem hopeless to attempt to discover this unknown background ; indeed, if ' the counterpart in the external world is of inscrutable nature ', it must be useless to attempt to scrutinize it. Still, Eddington says, since it must be attached to something,

why not ' attach it to something of spiritual nature of which a prominent characteristic is *thought* '. He urges that ' in one case—namely for pointer-readings of my own brain—I have an insight which is not limited to the evidence of pointer-readings. That insight shows that they are attached to a background of consciousness ' (*N.Ph.W.* 259). This insight is the only hint we have ' as to the significance of the background—namely, that it has a nature capable of manifesting itself as mental activity '. Consequently, he argues : ' *There is nothing to prevent the assemblage of atoms constituting a brain from being of itself a thinking object in virtue of that nature which physics leaves undetermined and undeterminable* ' (*N.Ph.W.* 260, italics his).

Unfortunately, this argument, ending in so triumphant a conclusion, is a complete muddle. Even if Eddington were right in maintaining that the physicist has a self-knowledge of that which is in his own consciousness, it cannot be admitted that he has such insight *into what is going on in his brain.* It might be contended that the physiologist has knowledge of the pointer-readings of *other people's* brains ; it cannot be maintained that he has such knowledge of his own brain. He may have awareness of the ' background ' of his own consciousness (whatever precisely that may mean), but he neither has, nor could conceivably have, insight that the pointer-readings of his own brain are attached to the background of his consciousness. Thus, with regard to other people's brains, his knowledge is nothing but a schedule of pointer-readings ; with regard to his own brain he has not even this knowledge except in so far as he constructs it from what he knows about other people's brains. Consequently, it must be urged that it is a complete muddle to argue that anyone has the insight that the pointer-readings of his own brain are attached to his own consciousness.

When Eddington comes to discuss the question, 'what is Mr. X?' (i.e. an *other* self), he says, 'I learn that Mr. X has carbon in his brain, but the *immediate* knowledge was of something (not carbon) in my own mind' (*N.Ph.W.* 269). In the next paragraph he adds: 'One feature of this inference is that I never discover what carbon really is. It remains a symbol. There is carbon in my own brain-mind; but the self-knowledge of my mind does not reveal this to me.' It is extraordinarily difficult to make any sense at all out of these statements. *Brain* is now hyphenated with *mind* but the self-knowledge is of the *mind* element in this hyphenated compound, not of the brain. Still, so far as I can gather, Eddington does not seem to regard it as essentially nonsensical to say that there might have been self-knowledge of the carbon in my own brain. He denies only that we have such self-knowledge. Yet, carbon is said to be a *symbol*. Surely a symbol just is something that a mind could be expected to know. Eddington would reply that we know carbon *as* a symbol; we do not know *of* what carbon is a symbol. Hence, our knowledge of carbon is what he calls 'merely symbolic knowledge'. It is for this reason, I think, that he insists that physics requires a supplement, for, if we know *that* carbon is a symbol we also know *that there is something* of which it is a symbol. But how could we possibly discover that carbon is a symbol, if we have no conception at all what it symbolizes?

This consideration must be pressed. We are all very familiar with the use of symbols both in the ordinary affairs of life and in the wholly symbolic means of communication by a written language. But in order to recognize an object, say a stone, as a symbol we must know that there is something that the stone has been used to symbolize. There is a symbolic, ritual significance in the circle of stones,

called Grey Wethers, on Dartmoor. That these stones were thus arranged with conscious intent is obvious to anyone, however ignorant he may be with regard to that intent. But it is not at all obvious that *carbon* is a symbol; on the contrary, the notion that it may be a symbol is rather shocking. So much so, indeed, that Eddington himself wavers between saying that carbon *is* a symbol and that it is 'described' by a symbol. He wants, however, to regard carbon as a symbol. He says: 'Carbon is a symbol definable only in terms of the other symbols belonging to the cyclic scheme of physics.' If, therefore, we are to understand what carbon is we must know what it symbolizes. True enough, if carbon *be* a symbol. But what warrant is there for supposing that it is?

I do not think that Eddington ever faces the necessity of asking this question. Still less does he attempt to provide an answer to it. But it is not difficult to see the confusion in his thinking that has led him to assume that carbon, and everything else in the physical world and in the familiar world, is merely symbolic. To make clear what these confusions are it is necessary to reconsider at some length Eddington's view of the way in which we come to discover that the familiar world is an illusion and that the world of physics is a symbolic world shadowing the familiar world.

It will be remembered that Eddington takes the external world to be the source of messages that are transmitted along the nerve fibres into the brain. The nature of the transmitting mechanism makes it impossible that there should be conveyed through it any information as to what the original source of the message is like. To suppose otherwise would be to make the mistake of supposing that the writing on a telegram issued from a post office

is like the writing of the person who wrote the telegram in another post office on a form that the recipient of the telegram does not see. Thus, for instance, the transmitting mechanism cannot transmit *colour*; hence, the colours that I see are spun by my own mind.[1] The following passage is significant:

> This limitation of the transmitting mechanism is strikingly illustrated when we talk with a colour-blind person. We know from his amazing mistakes that there is a big difference between his perception of his surroundings and ours. But he is quite unable to convey to us how his perception differs. When he confuses red with green, does he see both colours as red or both as green or as some hue unknown to us? He has no means of telling us. The intrinsic nature of his perception is trapped in his mind. It cannot flow out along his nerves; nor could it travel up our nervous system if it reached us. Similarly the sensory qualities of colour, sound, and scent cannot have been transmitted to us from the object in the external world to which we attribute the colour, sound and scent; for even if we suppose the object itself to be endowed with such qualities it would be as impotent as the colour-blind person to convey to us their character. The part played by the external object is to condition directly or indirectly the signals which pass along the nerves. (*N.P.Sc.* 5.)

This is an amazing argument. The fact that we have knowledge of our nervous systems, the processes in the nerve fibres, and of states of the brain is used to establish the conclusion that we do not possess knowledge of the external world in which are to be found nervous systems, neural processes and brain states. The 'intrinsic nature' of the colour-blind man's perception is said to be 'trapped in his mind'; so, too, in your case and in mine. The consequence of such a view is that what I 'directly know' is in my head. Nevertheless, I am said to have symbolic knowledge of a world outside my head. How, along the lines of the above argument, this should be supposed to be

[1] See *N.P.Sc.* 4, and cf. pp. 63–4 above.

possible, it is difficult to discover. For, to have such knowledge of the external world, I must surely have to compare the structure of what I perceive (i.e. the effect of the external stimulus) with the external source (i.e. the unknown cause of the perception). To compare an effect in my head with its wholly unknown cause does seem to be an impossible feat.

Eddington has indeed fallen into the error of which Berkeley accused the Newtonians, as we saw in Chapter III. It is a very common error and consists in confusing the conditions of perception with the objects of perception. Yet these conditions are discoverable only by the perception of *other* objects. Eddington says that we infer the external source only by reversing 'the steps of the physical transmission which brought the information'.[1] But this is the old difficulty over again. Either the story-teller does give us information accurate as far as it goes or he does not. If he does, then there is no warrant for saying that the intrinsic nature of my perception is trapped in my mind; there is warrant only for saying that the information is not complete. If, on the other hand, the 'information' is entirely editorial invention, then it becomes an insoluble mystery how Eddington, or any other scientist, first discovered that the story-teller was telling lies.

It is not of course to be disputed that sometimes I am mistaken with regard to what I perceive. I may believe that I see an apple and it may turn out that what I saw was a fake. But there is no sense in saying that I am *sometimes* mistaken unless *sometimes* I am not. There is no sense in saying that I am suffering from an illusion unless I know what it is *not* to be suffering from an illusion. Yet, as we have seen, Eddington is constantly saying things of this sort. Confusions of this sort are, as I said above, by no

[1] *N.Ph.W.* 270. Cf. p. 278.

means uncommon. Mr. Joad, in discussing the bearing of physical discoveries upon the problem of perception, also argues that what is causally nearest to the brain is what is most certainly known. 'In general', he says, 'the nearer the starting-point of the physical process which consists in the propagation of light rays is to the brain, the less likely are we to be mistaken in our inference as to the nature of its origin; but directly we go beyond the bare statement "the optic nerve is being stimulated in such and such a way" and conclude "I am seeing an object of such and such a character", we are drawing an inference and are, therefore, liable to fall into error.'[1] Here Mr. Joad is merely echoing Bertrand Russell, whilst Eddington once more repeats their mistakes. I am aware that this statement is extremely dogmatic. But I do not wish to argue once more against a mistake that has surely been often enough exposed. The existence of the optic nerve, of the nervous process and of the consequent brain state can only be established by inference; it is only by inference that it can be known that the optic nerve *is* being stimulated. It is only because Russell and Joad *first* know that there are external objects that they are able to *infer* that there are private sensa.[2] It is only because the scientists are able to perceive the familiar furniture of the earth that they are able to discover the presence of electromagnetic waves. It is only because they are able to perceive the solidity of a piece of iron that they are able to discover that the atoms are tenuous. Unless the iron were solid there would be no point in saying that the atoms are tenuous.

[1] 'Realism and Modern Physics'—a symposium published in *Aristotelian Society: Supplementary Vol. IX*, p. 132.

[2] *I have dealt with this point in my contribution to the symposium* of which Mr. Joad's article forms part. See pp. 157 *seq.*

I have laboured this point at great length. I do not know that I have laboured it unduly. Eddington shares with Joad, and presumably with Mr. Russell, the belief that it is from physics that we discover what is 'really there'. He believes also that the universe contains nothing but mind and the entities dealt with by physics. But colour is not a physical property of events. Hence, colour must be regarded as 'mere mind-spinning'. This, however, leads us to a fresh difficulty, peculiar to Eddington. I am said to have a self-knowledge of my own mind. But I certainly have no self-knowledge of its powers of spinning colours. I can hardly believe that Eddington has such self-knowledge. Yet, if not, how does Eddington know that 'the mind' spins the colours that we attribute to the external world? Again, 'the substratum of everything is of mental character' (*N.Ph.W.* 281). Is colour to be included in the substratum of everything? I hardly think that Eddington intends to assert this, but it seems to follow from what he says. Again, how are we to understand the mechanical metaphor of *spinning* thus used in relation to mind? I suggest that in the context in which Eddington here uses it the word "spinning" is devoid of sense.

It is by such confused thinking that Eddington has come to believe that carbon is a symbol, that colour is a symbol—in short, that everything in the mind-brain is a symbol of something outside the mind-brain, and inferred by reversing the steps of the physical transmission. He assumes, indeed, a twofold symbolism. First, colour symbolizes electromagnetic waves, the former being in my mind, the latter in the external world. Secondly, these waves again are symbols; they symbolize an unknown, and indeed inscrutable something.

The second line of argument, referred to above, which is

elaborated in *New Pathways of Science*, is the argument that 'our present conception of the physical world is *hollow* enough to hold almost anything' (313), that this hollow scheme of symbols must be filled, and that the physicist is not competent to fill it. Elsewhere, Eddington had summed up our knowledge of the electron as follows: '*Something unknown is doing we don't know what*—that is what our theory amounts to' (*N.Ph.W.* 291). As a physicist (or ought we to say as a popularizer of physics?) he seems to revel in these unknowns; as a philosopher he demands that the unknown should be made known.

The one assumption that Eddington never questions and that has determined his whole philosophy is that there is an 'inscrutable absolute behind phenomena'. In his deservedly popular book, *Space, Time, and Gravitation*,[1] he tells a tale of a future antiquarian investigation, which is supposed to take place about the year A.D. 5000. A volume is found containing 'a large number of games of chess, written out in the obscure symbolism usually adopted for that purpose'. There is, of course, no information in the book as to the shape or size of the pieces, or of the colour and shape of the board. But by careful study the antiquarians discover certain uniformities, and, in spite of the fact that chess had long since been forgotten, they 'at last succeed in establishing beyond doubt the nature of the moves and rules of the game'. 'But', Eddington continues, 'it is obvious that no amount of study of the volume will reveal the true nature either of the participants in the game —the chessmen—or the field of the game—the chessboard.' In this illustration the chessmen are the entities of physics, the recorded games are physical experiments, and the rules of the game are physical laws. 'By no amount of study of

[1] See p. 184.

the experiments', Eddington insists, 'can the absolute nature or appearance of these participants be deduced; nor is this knowledge relevant, for without it we may yet learn "the game" in all its intricacy.'

Once again Eddington has used a merely illustrative analogy as an argument, and the analogy breaks down just in those respects which are vital for the argument. He has entirely forgotten to place himself in the position of his fictitious antiquarians. They could have no reason to suppose that the mark Kt—KB3 *stands for* 'move Knight to King's Bishop's third square', any more than they have reason to suppose that "Kt" *stands for* a material object of a certain sort of shape. That is to say, they have no reason to suppose that the symbols *mean* 'move a certain shaped material object along a certain hard board in a certain manner'. If the volume which they discovered had contained a large number of completed games of noughts and crosses, the antiquarians might have worked out the rules in accordance with which each game came to an end. They would have had no reason to suppose that **O** and **X** *stood for* something else, i.e. for something other than the elements obeying the rules of the game and in terms of which alone the rules could be stated. Nor, in this case, would Eddington have supposed otherwise. But in the case of the games of chess, *Eddington, the chessplayer,* knows that "Kt" stands for a certain sort of shaped chessman, and that "Kt—KB3" stands for a certain movement of that piece along a marked board, containing 64 squares. Accordingly, Eddington can argue that his antiquarians have a purely formal knowledge of a game about which they *might have known something more.* He can thus argue because *he* knows that there is more to know of which the antiquarians are, and must remain, ignorant. But the antiquarians could not know *that* there

was anything more to know. How, if we pursue the analogy, does Eddington know that there is more to know about electrons than is revealed by physical experiments? For, on his own showing, he is now in the position of the antiquarians studying the forgotten game of chess.

What is *meant* by the assumption that things have 'true natures' not revealed by experiment? How does the physicist ever succeed in making the discovery that physical laws are symbolic of 'true natures' that are inscrutable? How, finally, could the study of physics lead to the discovery that there are inscrutable natures which are 'some kind of counterpart in the external world' of that which is in our minds?

That these questions are unanswerable because they are absurd is concealed from Eddington owing to his habit of thinking in terms of bad metaphorical illustrations which he mistakes for arguments. In one of the many passages in which he uses the transmitter type of argument he says:

> The mind as a central receiving station reads the dots and dashes of the incoming nerve-signals. By frequent repetition of their call-signals the various transmitting stations of the outside world become familiar. . . . But a broadcasting station is not *like* its call-signal; there is no commensurability in their nature. So too the chairs and tables around us which broadcast to us incessantly those signals which affect our sight and touch cannot in their nature be like unto the signals or to the sensation which the signals awake at the end of their journey.. (*S.U.W.* 23.)

Here the analogy of the broadcasting station is unwarrantably transformed into the metaphorical statement that *chairs* broadcast *signals* to us. This metaphorical statement is then illegitimately transformed into the argument that *just as* the broadcasting station is not like its call-signal, *so* the chair in its own nature is not like what we perceive the chair to

be. This argument slides over the important question whether there is *any sense* in asking what chairs are 'in their nature'. It slides over it because *we* know, and Eddington knows, that wireless signals are broadcast from a station, and that electromagnetic waves are not like the sounds we hear nor 'like' the station from which they are sent out. But it is just at this point that the analogy breaks down. We know that a broadcast station has a nature of its own, that the announcer has a nature of his own, and that we shall not discover what either is simply by 'listening-in'. But what reason is there for supposing that a chair has a nature utterly unlike how it behaves and what it is perceived as? If, *per impossibile*, there were any sense in making such a supposition, how could anyone expect to be able to know how to set about finding an answer to it? Eddington's metaphorical illustrations instead of being illuminating or providing the hint of an argument gratuitously create a puzzle.

This puzzle is very obvious in Eddington's cryptogram illustrations, to which reference was made in Chapter V. To recognize a set of marks as a cryptogram it is necessary to know that the apparently meaningless collection of marks has been used by some one to stand for something else. In order that the cryptogram should be *understood* two conditions are necessary. First, the cryptogram must be deciphered; secondly, the decoded sentence must say something intelligible. At the heading of this chapter there is a cryptogram. It is constructed in a very simple manner. The reader should have no difficulty in deciphering it; the words are clearly separated and the key is easy to discover. When it is decoded, it will be found to make an English sentence—in fact, a sentence taken from one of Eddington's books. Whether the reader would understand what is said is not so certain. I confess for my part that I am doubtful

as to its precise significance. However that may be, it is worth while to ask ourselves what had to be known in order that the cryptogram might be deciphered. I suggest that the possibility of solving it depends upon our knowing the letters of the alphabet and the spelling of certain English words. But when Eddington speaks of decoding the messages from the outside world, no similar conditions are supposed to be fulfilled. In this enterprise we are indeed in the position of a man who finds a cryptogram composed of such marks as 'I567²ix' and has no means at all of knowing what the familiar-looking marks refer to. To solve it he must know *at least* that the basis of the code is the *Shorter Oxford English Dictionary*. He may then guess that I stands for volume I, 567 for the number of the page, the raised ² for the column, and ix for the number of the entries in that column starting from the top. If he consulted the dictionary, he would find that the word is **drugget.** This is to know a great deal. But the decoding physicist in Eddington's arguments is, as we saw, in an utterly different position. He has no reason at all to suppose that he is confronted with a code; if he supposes that he is, he will then make the discovery that he has no means of solving the coded message. Eddington, I imagine, would reply that he would be in this desperate case were it not for the fact that the code has been created by mind, and that what mind creates mind can rediscover. Such would seem to be the consequences of the descent to the inscrutable and the attempt to scrutinize the inscrutable.

There can be no doubt, I think, that Eddington himself has been genuinely puzzled. He is not, I think, merely befooling the reader—at least, not all the time. Unfortunately, however, he has never discovered that his puzzlement has been caused by his initial assumptions which led

him to ask unanswerable because meaningless questions. He believes that he has solved his puzzles. But the answers he has given to his questions are unintelligible. This is not surprising. How else could an unanswerable question be answered ?

Part III

CAUSALITY AND HUMAN FREEDOM

'Life is a pair of scales where men must weigh
Imponderable things and things of clay.'

SUSAN MILES

Chapter VII

THE NINETEENTH-CENTURY NIGHTMARE

> Others apart sat on a hill retired,
> In thoughts more elevate, and reasoned high
> Of Providence, Foreknowledge, Will, and Fate—
> Fixed fate, free will, foreknowledge absolute—
> And found no end, in wandering mazes lost.
>
> JOHN MILTON

THE common reader cannot fail to be aware that contemporary physicists have been re-considering 'the old conflict between free will and predestination', in which, says Eddington, 'it has seemed hitherto that physics comes down heavily on the side of predestination' (*N.Ph.W.* 293). He himself holds that now physics 'comes down', if not heavily, at least decisively, on the side of free will. 'On the scientific side', he says, 'a new situation has arisen. It is a consequence of the advent of the quantum theory that *physics is no longer pledged to a scheme of deterministic law.*' The far-reaching influence of such statements upon the common reader is amusingly illustrated in a review of Mrs. Dugdale's life of A. J. Balfour, which appeared in the *Times Literary Supplement* for 19 September 1936. The reviewer, reflecting upon the vicissitudes of Balfour's political career, poses the question: 'How could a man whose life was so much of a piece thus touch the extremes of public obloquy and public veneration?' He suggests that the explanation is to be found in the sup-

position that 'the public adjusted itself to Balfour, and that the times eventually caught up with the forward-ranging mind which so long moved ahead of them'. We are not here concerned to consider the soundness, or otherwise, of the theory put forward to account for the changes in the public estimation of Balfour. What is of interest for our present discussion is the reviewer's attempt to find support for his theory in the contemporary scientific situation. He gravely urges: 'Modern physics gives it, indeed, some countenance. Confronted with the evidence of probability in nature, of a sphere in which the satisfying rules of cause and effect cease to apply, it suggests that things are in some way affected by our thought upon them, becoming more certain as it grows more definite. If this be so, what limits shall we set to the influence on the contemporary intellectual universe of a mind so vigorous, comprehensive, inquiring and sceptical as Arthur Balfour's?' Surely this is a surprising use of scientific speculations based upon the phenomena of quantum physics. In the following chapters an attempt will be made to show that this attempt to find countenance for a theory of the interaction of human beings upon one another is as unwarranted as it is surprising.

Undoubtedly the bearing of the 'Law of Universal Causation' (to use a favourite nineteenth-century phrase) is a problem much in evidence in the discussions of our philosophizing scientists. It is commonly admitted that at one time the scientists were informing us that 'free will" was an illusion, that we were all constrained to act—in whatever way we did in fact act; that if we were wicked, it couldn't be helped, and if we were good—well, that was nothing to be complaisant about. Nowadays, it is commonly supposed that these conclusions were premature, that if the biologists were compelled to deny to us freedom

of action that was because they did not see sufficiently deeply into the constitution of matter ; now, however, the physicists have come to our rescue and have argued that, if an electron is ' free to choose ' where it will go, surely a man may choose whether he will spend his summer holidays at Margate or at Wiesbaden, or whether he will propose to an heiress or remain a bachelor. Along with this proclamation of the rights of the intuition of free will, based somehow upon its being something other than an intuition—namely, a deliverance of consciousness in conformity with the most refined knowledge of the expert physicist—there goes an increasing reliance of the common reader upon the ability of the physicist to tell us what will happen to some one looking at the sun from the Cornish Coast on 11 August 1999, and what will happen to the non-combatants in the next world war.

The situation is sufficiently curious. Upon the one hand we rely increasingly upon the scientist, biochemist, physiologist, and physicist, to tell us how to breed men and women for a ' brave new world ' and what, if we disregard their advice, will happen to our descendants ; on the other hand, we rejoice to be told that the physicist is less certain now than he was a few years ago that he does, or ever can, know what will happen. The position assigned to science in general, and to this or that particular scientist, is curious enough. We common readers continue to look up to them as the repository of knowledge and begin to regard them as the custodians of the spiritual element in the universe. They —or to speak more moderately some of them—have long aspired to the mantle of the prophets ; now we thrust the mantle upon them. Theologians have, in the past, claimed to speak with a higher authority about higher things than those with which the scientist is concerned ; now the

theologians hang on to the mantles—or is it only the coats ?—of the popularizing scientist. The situation does not lack an element of comedy.

The work of Descartes, Kepler, Galileo, and Newton laid the foundations of a scheme of deterministic law that for nearly three centuries has been unhesitatingly accepted by the physical scientists. Developments in physics were consistent with, and indeed dependent upon, the assumption that the movements of matter took place in accordance with certain ascertainable laws such that, given sufficient data concerning some finite period of time, however short, it would be theoretically possible to calculate all earlier and later material configurations. The impact of this stupendous theory upon the beliefs of the man in the street was but slight. The deterministic scheme was conceived as applying only to matter, and, for the most part, its application was limited to non-living matter. Human beings were regarded as privileged, although, perhaps, no one was very clear as to the source or the scope of this privilege.

The advent of the biological theory of evolution introduced a profound change by denying that men were specially privileged. Men in the street, or at least congregations in churches, began to be aware that certain scientific theories were being developed which were hostile to their religious and moral beliefs. I think that it may safely be said that the common reader's intense interest in the latest developments of quantum theory, represented for him by 'the Principle of Indeterminacy', is due to his belief that fresh light has been thrown upon the 'old conflict between free will and predestination'—to requote Eddington's phrase. This conflict was forced upon the attention of plain men by the rise of evolutionary biology in the second half of last century. As the name, 'Natural Selection', given to

Darwin's theory of the origin of species, shows, the foundation of evolutionary biology lies in the acceptance of the view that animal species, including man, originate and develop in accordance with natural laws. T. H. Huxley, the great popularizer of Darwinism, was a firm believer in the possibility of extending 'the reign of law' from mechanical and chemical phenomena to the phenomena of biological development, and thence to the mental life of human beings. It is worth while, in this context, to quote from one of his most famous Addresses—a discourse delivered on 8 November 1868, in Edinburgh, entitled 'On the Physical Basis of Life'.[1] His intention was to convince his hearers that the protoplasm which is the basis of 'the dull vital actions of a fungus' is 'essentially identical with and most readily convertible into, that of any animal', and that, consequently, 'all vital action may . . . be said to be the result of the molecular forces of the protoplasm which displays it'. Consequently, he went on to urge, 'the thoughts to which I am now giving utterance, and your thoughts regarding them, are the expression of molecular changes in that matter of life which is the source of our other vital phenomena'. He took special pride in pointing out that this language is materialistic, and equal pride in proclaiming his 'repudiation of materialistic philosophy' which involves 'grave philosophical errors'. He was insistent that sound logic necessitated 'this union of materialistic terminology with the repudiation of materialistic philosophy'. This insistence had a point. 'I purposed', he said, 'to lead you through the territory of vital phenomena to the materialistic slough in which you find yourselves now plunged, and then to point out to you the sole path by which, in my judgement, extrication is possible.'

[1] *Method and Results: Essays* (1893), pp. 130–65.

(p. 155.) This path is found when we recognize that we know nothing more of 'cause and effect than a certain definite order of succession among facts'.

Huxley's point of view is so curious, so unfamiliar, and so widely adopted by his scientific contemporaries, that it is advisable to quote in full a most significant passage:

> I ask you what is the difference between the conception of life as the product of a certain disposition of material molecules, and the old notion of an Archaeus governing and directing blind matter within each living body, except this—that here, as elsewhere, matter and law have devoured spirit and spontaneity? And as surely as every future grows out of past and present, so will the physiology of the future gradually extend the realm of matter and law until it is co-extensive with knowledge, with feeling and with action.
>
> The consciousness of this great truth weighs like a nightmare, I believe, upon many of the best minds of these days. They watch what they conceive to be the progress of materialism, in such fear and powerless anger as a savage feels, when, during an eclipse, the great shadow creeps over the face of the sun. The advancing tide of matter threatens to drown their souls; the tightening grasp of law impedes their freedom; they are alarmed lest man's moral nature be debased by the increase of his wisdom.

After this impassioned outburst, Huxley suggests that Hume would chide these fear-filled people for 'falling down in terror before the hideous idols their own hands have raised'. The 'idols', it seems, are 'matter' and 'spirit'. 'What', asks Huxley, 'do we know of this terrible "matter" except as a name for the unknown and hypothetical cause of states of our own consciousness?' Again, 'what do we know of that "spirit" over whose threatened extinction by matter a great lamentation is arising . . . except that it is also a name for an unknown and hypothetical cause, or condition, of states of consciousness?' Thus, he concludes, 'matter and spirit are but names for the imaginary substrata of groups of natural phenomena'.

It is, however, to be noticed that a few pages earlier Huxley had asserted confidently, ' anyone who is acquainted with the history of science will admit, that its progress has, in all ages, meant, and now, more than ever, means, the extension of the province of what we call matter and causation, and the concomitant gradual banishment from all regions of human thought of what we call spirit and spontaneity '. Thus, according to Huxley, the progress of science has consisted, is consisting, and will increasingly consist, in the extension of ' the province ' of the ' imaginary substrata of groups of natural phenomena '. This is described by Huxley—somewhat inappropriately, as I hope he would have admitted—as ' the extension of the province of matter '.

Huxley's rhetorical flights make it a little difficult to disentangle the main points of his arguments, to be quite clear as to what exactly it is he is defending, what he is attacking, and what he believes others to have defended or attacked. But certain points can be discerned with sufficient clearness to be worth discussion. He is attacking the view that there is an ' iron law ' which *necessitates* human actions ; he is maintaining that human actions are, or with increased knowledge will be, wholly describable in physiological terms, and that they may therefore be regarded as instances of natural laws. He replaces the view which he rejects by the view that laws of nature state what ' will happen ', not what ' *must* happen '. He maintains that the correct language to use is that ' an unsupported stone *will* fall to the ground ' ; it is incorrect to say that ' it *must* fall to the ground '. Finally he protests : ' But when, as commonly happens, we change *will* into *must*, we introduce an idea of necessity which most assuredly does not lie in the observed facts, and has no warranty that I can discover elsewhere.

For my part, I utterly repudiate and anathematize the intruder. Fact I know; and Law I know; but what is this necessity, save an empty shadow of my own mind's throwing?' (p. 161).

This, then, is Huxley's method of dispelling the nightmare. The demon he has 'exorcized' is 'the materialistic position that there is nothing in the world but matter, force, and necessity'. But in exorcizing the demon he has been led to insist that human actions are wholly expressible in terms of physiological laws. The 'necessity' which he utterly repudiates and anathematizes is physical necessity. It is extraordinarily difficult to see what Huxley's repudiation amounts to. A few pages earlier he had proclaimed: 'I take it to be demonstrable that it is utterly impossible to prove that anything whatever may not be the effect of a material and necessary cause, and that human logic is equally incompetent to prove that any act is really spontaneous' (p. 159). How is 'necessary' to be interpreted in this context? Its conjunction with *material*, in the expression 'material and necessary cause' is inexplicable when we remember that Huxley denied that the notion of physical necessity had any sense. 'The notion of necessity', he says, 'is something illegitimately thrust into the perfectly legitimate conception of law' (p. 161). It has, he elsewhere maintained, 'a logical, not a physical foundation' (p. 245.) It would seem, then, that it is by a pen slip that Huxley wrote 'a material and necessary cause' in the statement quoted above. Be that as it may, it is by denying that necessity has a physical foundation that Huxley sought to escape from the nightmare induced by the 'great truth' of the advancing tide of matter which threatens to drown our souls.

His escape from materialism is no less puzzling in view

of his belief that human beings are conscious automata. He is not, he insists, to be ranked among the materialists since, he says, 'I am utterly incapable of conceiving the existence of matter if there is no mind in which to picture that existence.' This statement directly follows an attempt to establish the contention that all states of consciousness in human beings and in brutes are 'immediately caused by molecular changes of the brain-substance'. This contention is of such great importance for our present inquiry that his statement must be quoted in full.

> 'It seems to me that in men, as in brutes, there is no proof that any state of consciousness is the cause of change in the motion of the matter of the organism. If these positions are well based, it follows that our mental conditions are simply the symbols in consciousness of the changes which take place automatically in the organism; and that, to take an extreme illustration, the feeling we call volition is not the cause of a voluntary act, but the symbol of that state of the brain which is the immediate cause of that act. We are conscious automata endowed with free will in the only intelligible sense of that much-abused term—inasmuch as in many respects we are able to do as we like—but none the less parts of the great series of causes and effects which, in unbroken continuity, composes that which is, and has been, and shall be—the sum of existence.

According to this statement human beings are 'parts of the great series of causes and effects' which compose 'the sum of existence'. Human beings, that is to say, belong to Nature. Nature is an unbroken continuity of material causes. Our mental conditions are symbols in consciousness of the changes which occur automatically in the living organism, i.e. in part of the great series of causes and effects. Volitions are not among these causes; a volition is a symbol of a state of the brain. These contentions might certainly be regarded as affording an adequate foundation for the 'nightmare' which, according to Huxley, weighed upon 'the best minds' of the nineteenth century. What, we

may ask, is consciousness? Huxley would reply that consciousness is an epiphenomenon, or by-product, of the material organism. But he also maintained that the existence of matter is inconceivable 'if there is no mind in which to picture that existence'. But if mental conditions are symbols in consciousness of changes in the organism, and if the organism, being material, cannot exist save in mind, it is difficult to know what we are to understand by "mental conditions", and impossible to have any clear conception of how mental conditions are related to the consciousness *in which* they are symbols of bodily changes.

It is evident that Huxley had never thought it worth while to inquire what a symbol is, nor to consider what he meant by 'an expression'. Had he done so, he might have avoided some of the glaring inconsistencies into which he fell in attempting at the same time to escape from the nightmare, to develop the consequences of his doctrine of conscious automata, and to enforce the lesson he never wearied of preaching, namely, that it is 'the plain duty of each and all of us to try to make the little corner he can influence somewhat less miserable and somewhat less ignorant than it was before he entered it'. For the performance of this duty he thought we must believe first, that we can ascertain the order of Nature; secondly, that 'our volition counts for something as a condition of the course of events'. In republishing the Address, in 1892 (i.e. more than twenty years later), he added the surprising footnote: 'Or, to speak more accurately, the physical state of which the volition is the expression.' The footnote is surprising since it is in such flat contradiction with the original statement, although it is put forward as more accurate. If our *volition* is to count for something as a condition of the course of events, it might be supposed that the

physical state is the expression of the volition—provided that the word "expression" is to be used at all. But according to the footnote the volition is the expression of the physical state. Huxley's language is, as is often the case, so imprecise that it is not easy to be sure what is meant, but it is probable that he is merely saying that physical states of human bodies are causal factors in the course of natural phenomena. This interpretation is in conformity with Huxley's view that volition is not the cause of a voluntary act but a feeling which, with other mental conditions, is but a symbol in consciousness of changes occurring automatically in the body. This interpretation cannot, however, be reconciled with the second condition, namely, that our volition should *count* for something as a condition of the course of events. This is surely obvious, for, since the volition is the expression of the physical state, this physical state must itself have been caused by other physical states, and must have still other physical states as its effect; these will form part of the 'great series of causes and effects', and thus will be 'assuredly what they will be'. In that case, it is difficult to attach any meaning to the statement that we 'can influence our little corner' as the result of 'doing our duty'. Huxley has, indeed, left untouched the conception of natural law, whilst stressing the universality of its application. Human actions are free in the same way precisely as an unsupported stone is free to fall to the ground.

It is not to be wondered at that the Bishops did not enthusiastically acclaim Huxley as an ally in the defence of spiritual freedom. What, we may ask—adopting the rhetorical style so dear to Huxley himself—what is required in order that our volition should *count* for something? What, again, is the point of distinguishing between "matter" and "spirit" since 'both are but names for imaginary

substrata of natural phenomena'? Huxley was himself eager to admit that it was all an affair of terminology. 'In itself', he says, 'it is of little moment whether we express the phenomena of matter in terms of spirit; or the phenomena of spirit in terms of matter; matter may be regarded as a form of thought, thought may be regarded as a property of matter—each statement has a certain relative truth.' Huxley's lack of clarity here is no doubt bound up with his failure to see that, if there were cause for a nightmare, he had not removed it. To say that 'the great series of causes and effects' which composes 'the sum of existence' may be indifferently called 'matter' or 'spirit' is not to throw any light upon the questions which were of such interest to Huxley's contemporaries. It was enough for Huxley himself to believe that we 'could do' our 'plain duty'. This he certainly believed. It never occurred to him to ask what is involved in the notion of *doing one's duty*; he thought it sufficient to maintain that we had 'free will' in the sense that 'we are able to do as we like', whilst leaving our *likings* within the great causal series of phenomena. Thus Huxley never felt the sting of the problem; he escaped from the nightmare only in the sense that he never entered into it.

Some years before Huxley entered the arena in defence of Darwin's theory of Natural Selection, J. S. Mill had raised the question whether it is possible 'to treat of human conduct as a subject of science'.[1] The affirmative answer to this question presupposed, he held, that the actions of human beings are 'like all other natural events, subject to invariable laws'. There is some tendency to beg the question in this statement. For, if human actions are to be included among 'other natural events', then the question

[1] *Logic*, Bk. VI, Chap. I, § 2.

whether or not human actions are subject to 'invariable laws' is settled as soon as it is known whether *all* natural events are subject to invariable laws. That natural events were so subject, Mill had, of course, endeavoured to prove. His procedure seems, however, to have been to attempt to show that human actions are 'subject to invariable laws', and that, *therefore* human actions fall within the series of natural events.[1]

Although, so far as I know, Mill does not explicitly state that the aim of science is prediction, he certainly insisted that predictability is the sign of a law of nature. He wanted to establish that there are discoverable natural laws, and that these natural laws can be known to be certainly true. Such laws he believed to be causal laws. On Mill's view, a causal connexion is one which always *will* hold, not merely one which always *has* held. A causal connexion must, then, be *unconditional*, i.e. must hold 'under all imaginable circumstances'. It is in the sense of stating an unconditional, and thus invariable, connexion that a causal law contains the notion of *necessity*.[2] The question, then, whether human actions are necessitated is equivalent to the question whether there is an unconditional connexion between a given human action and an event upon which it is consequent. 'When we say that all human actions take place of necessity', Mill remarks, 'we only mean that they will certainly happen if nothing prevents.'[3] Mill assumes that it is theoretically possible to predict what 'will certainly happen', and that

[1] Cf. *ibid.*, Bk. III, Chap. V, § 11. 'Our will causes our bodily actions in the same sense, and in no other, in which cold causes ice, or a spark causes an explosion of gunpowder.'

[2] See loc. cit. 'That which is necessary, that which *must* be, means that which will be, whatever supposition we may make in regard to all other things.'

[3] *Logic*, Bk. VI, Chap. II, § 3.

what can be predicted will certainly happen. On the face of it, it would seem that some human actions are predictable, but that others are not. But, Mill argues, ' whoever knew the motives, and our habitual susceptibilities to them, could predict how we should will to act '. Mill regarded this contention as simply an interpretation, almost a transcription, of facts open to anyone's inspection, if he would but reflect. Any doubts that might arise would be due to the complexity of the facts, and to the extreme difficulty of ascertaining the antecedents of human action, i.e. of knowing the character of the person concerning whom the prediction is to be made and of detecting the motives that were operative. This is a difficulty in practice, not in principle.

Mill's conclusion is, then, that human actions are necessitated, provided that we understand the word ' necessitated ' aright. We must be careful to avoid the supposition that there is ' some peculiar tie or mysterious constraint, exercized by the antecedent over the consequent '. The false belief that ' causes draw their effects after them by a mystical tie ' is, Mill believes, at the root of the objection to the view that human actions are necessitated. In other words, a mistaken analysis of the statement *A causes B* has led to the repudiation of the correct view concerning human actions. The mistaken view is that ' we have no power of altering our character '. The correct view is that we are able to alter our character *if we wish*. This wish is itself an antecedent to the action upon which the action is causally consequent. Mill distinguished three views with regard to the causation of human actions. The first is the doctrine of Necessity ' properly understood '. This is his own view, which he named ' the doctrine of Philosophical Necessity '. The second is the doctrine of Necessity ' improperly understood '. This is hardly to be distinguished from Fatalism. What is

improper in this view is the contention that our character is formed *for* us, not *by* us, so that even if we wish to alter our character we cannot do so. We struggle hopelessly against Fate. Mill insisted that his own doctrine left men masters of themselves. The third view is the doctrine of Free Will. This appears to be [1] the view that human actions may be free, and that when they are free they are uncaused. A free action, on this view, is spontaneous in the sense in which Huxley used that term. This view Mill rejected but he thought that it kept in view 'a portion of the truth which the word Necessity put out of sight, namely, the power of the mind to co-operate in the formation of its own character'.

It cannot be said that Mill's view of human action is at all clear. Nevertheless, he did see far more clearly than was later to be the case with Huxley, that the extension of the reign of law was at least apparently in conflict with the common man's conception of the conditions under which moral action is possible. The way in which he sought to solve the apparent conflict is instructive for the purposes of this discussion. To Mill it seemed enough to show that there is no hidden nexus, no 'peculiar tie' between the antecedent and the consequent, between the motive and the act. 'If such a tie is considered to be involved in the word necessity', Mill remarked in an important passage, 'the doctrine is not true of human actions; but neither is it then true of inanimate objects. It would be more correct to say that matter is not bound by necessity, than that mind is so.' [2] Thus Mill concludes that mental events and physical events exhibit the same mode of connexion, a mode which fits both alike to be the subject of true predictions.

[1] I say "appears to be" because it is by no means easy to determine what exactly the doctrine of free will is intended to be.

[2] *Logic*, Bk. VI, Chap. II, § 2.

Chapter VIII

THE REJECTION OF PHYSICAL DETERMINISM

'And to us it is enough that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea.

And now we might add something concerning a certain most subtle Spirit which pervades and lies hid in all gross bodies; by the force and action of which Spirit the particles of bodies mutually attract one another at near distances, and cohere, if contiguous; and electric bodies operate to greater distances, as well repelling as attracting the neighbouring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies; and all sensation is excited, and the members of animal bodies move at the command of the will, namely by the vibrations of this Spirit, mutually propagated along the solid filaments of the nerves, from the outward organs of sense to the brain, and from the brain into the muscles. But these are things that cannot be explained in a few words, nor are we furnished with that sufficiency of experiments which is required to an accurate determination and demonstration of the laws by which this elastic and electric spirit operates.'

NEWTON

WE have now to consider what precisely is meant by the statement that physicists did formerly believe in determinism but that now they do not. The best way to approach this problem is to attempt to understand what is involved in the conception of a deterministic scheme of law. For this purpose it is desirable to go back to Galileo, but not to consider the work of his predecessors.

The mediaeval scheme of the universe was a teleological scheme. Only final causes were regarded as capable of providing a satisfactory explanation of natural events, that is, of what happens in Nature. To Galileo belongs the merit of refusing to find in final causes, or in a Supreme Cause, the answers to those questions which men desire to put concerning what happens in Nature. Galileo believed that the Natural World was a vast system consisting of motions of matter in space and time, describable completely and solely in the language of mathematics. This conception of the mathematical nature of the material world was developed by Descartes. 'Give me matter and motion', he said, 'and I will construct the universe.'[1] By 'the universe' Descartes meant what we now call the 'physical world'. He definitely excluded from consideration the self, i.e. thinking substance, and seems never to have been profoundly puzzled by the question how thinking substance and matter—i.e. extended substance—were to be conceived as together constituting the unity of the human being. He was content with a radical dualism: one world consisting of a vast mathematical machine, extended in space; another world consisting of unextended, thinking substances, i.e. minds. Whatsoever is not mathematical is mental; hence, colours, tastes, sounds, smells, are extruded from Nature. The odd consequences of this extrusion have already been discussed. Here we are concerned only with the mathematical conception of the world, which may be interpreted as a scheme of deterministic law.

The title of Newton's great work, *Mathematical Principles*

[1] Eddington comments upon this statement—'The mind reverses this. "Give me a world—a world in which there are relations—and I will construct matter and motion"' (*Space, Time, and Gravitation*, p. 198). See p. 83 above.

of Natural Philosophy, well indicates the fundamental assumptions of the originators of modern science. Newton accepted the general view of Galileo and Descartes that the world of matter in motion was fundamentally mathematical in character. Unlike Descartes, however, Newton did not propose to construct the world by pure reason. He regarded the physical world as the sensible world whose properties must be experimentally determined. Fortunately the sensible world possesses characteristics that are amenable to mathematical treatment. These characteristics Newton regarded as fundamental—indeed, as the only real properties, with the result that we have seen. Yet, he insists,

> 'We no other way know the extension of bodies than by our senses, nor do these reach it in all bodies; but because we perceive extension in all that are sensible, therefore we ascribe it universally to all others also. That abundance of bodies are hard, we learn by experience; and because the hardness of the whole arises from the hardness of the parts, we therefore justly infer the hardness of the undivided particles not only of the bodies we feel but of all others. That all bodies are impenetrable, we gather not from reason but from sensation. The bodies which we handle we find impenetrable, and thence conclude impenetrability to be an universal property of all bodies whatsoever. That all bodies are moveable, and endowed with certain powers (which we call the *vires inertiae*) of persevering in their motion, or in their rest, we only infer from the like properties observed in the bodies which we have seen. The extension, hardness, impenetrability, mobility, and *vires inertiae* of the whole, result from the extension, hardness, impenetrability, mobility, and *vires inertiae* of the parts; and thence we conclude the least particles of all bodies to be also extended, and hard and impenetrable, and moveable, and endowed with their proper *vires inertiae*. And this is the foundation of all philosophy.'[1]

Having discovered these properties 'from sensation' Newton sought to bring all natural phenomena within the scope of mathematical mechanics. For Newton the importance of

[1] Op. cit., II, 161.

mathematics was that it provided an unrivalled instrument for physical investigations. In the Preface to the *Principles* this point of view is stated very clearly :

> We offer this work as mathematical principles of philosophy . . . by the propositions mathematically demonstrated in the first book, we then derive from the celestial phenomena the forces of gravity with which bodies tend to the sun and the several planets. Then from these forces, by other propositions which are also mathematical, we deduce the motions of the planets, the comets, the moon, and the sea. I wish we could derive the rest of the phenomena of nature by the same kind of reasoning from mechanical principles . . . but I hope the principles here laid down will afford some light either to that or some truer method of philosophy.

Certainly mathematics plays a central part in Newton's investigation of the physical world. Indeed, the *Principles* might be regarded as almost entirely a work on mathematics ; it is concerned with the geometry of motion. Contact with the object of Newton's investigations, namely, the sensible world, comes through the concepts of *mass* and *force*. Although it was upon the basis of experimental observations that Newton formulated his three Laws of Motion, they were not empirical generalizations.[1] As developed by Newton, the mathematical principles of natural philosophy provided the first deterministic scheme of law that we encounter in the history of science. His ' System of the World ' was a deterministic system.

Newton did not believe that the system of the world could be self-originating ; nor was it conformable to his habits of thought—habits which he shared with his contemporaries—to suppose that the question of origination is an idle one. Accordingly, he held that ' this most beautiful system of the sun, planets, and comets could only proceed

[1] See Chap. IV, p. 80–1, above.

from the counsel and dominion of an intelligent and powerful Being'.[1] The motions of this 'beautiful system' have been explained wholly in mechanical terms. The world is a vast machine, self-contained once it has been set going, but liable to occasional breakdowns.[2] Hence, God is necessarily presupposed as the designer of the machine; He is also required to intervene from time to time to repair its deficiencies. But, although God has an important part to play in the metaphysical background of Newton's Natural Philosophy, He does not enter into his calculations. It was left to Laplace to recognize that this divine intervention was not called for. He claimed to show that the irregularities of the world are periodic and can thus be brought within the formulation of law. Hence, Laplace needed not to make 'the hypothesis of God' in order to develop the deterministic scheme implicit in Newton's cosmology. This scheme may be said to have reached its culmination in Laplace's well-known conception of the supreme Calculator.

'We ought then to regard the present state of the universe as the effect of its antecedent state and the cause of the state that is to follow. An intelligence knowing, at a given instant of time, all forces acting in nature, as well as the momentary positions of all things of which the universe consists, would be able to comprehend the motions of the largest bodies of the world and those of the lightest atoms in one single formula, provided his intellect were sufficiently powerful to subject all data to analysis; to him nothing would be uncertain, both past and future would be present to his eyes. The human mind in the perfection it has been able to give to astronomy affords a feeble outline of such an intelligence . . . All its efforts in the search for truth tend to approximate without limit to the intelligence we have just imagined.'[3]

This statement must not be taken as equivalent to the

[1] Op. cit., II, 310. [2] Cf. Huyghens.

[3] *Théorie analytique des probabilities* (Paris 1820. 3rd. ed.).

useless tautology : ' If a supreme intelligence were to know everything that there is to know then he would know everything there is to know.' On the contrary, Laplace is making a definite statement about the world. Perhaps what this statement amounts to can be best explained by a simple example expressed in an old-fashioned manner. The supreme intelligence could obtain his formula provided that, for example, it were not the case that bodies attracted each other in accordance with a ' law ' of the inverse squares in the seventeenth century but in accordance with a ' law ' of the inverse cubes in the twentieth century. Or, again, if the velocity of light undergoes a variation in time, then the formula could not apply. In other words, it is assumed that physical laws are independent of the absolute time, i.e. that the differential equations in terms of which happenings in Nature are described do not contain explicit functions of the time. This may be interpreted by saying that the state of the world at *any given* time determines its state at *any other* time, whether earlier or later than the given time. Thus, for instance, if the supreme intelligence had complete information with regard to the state of the world during the first second of the year 1937, he could calculate what would be happening at any subsequent date (say, during the last second of the year A.D. 2999) and also what had been happening in the world at any earlier date (say, during the first second of the year 11843 B.C. [1]). It is in this sense that ' past and future would be present to his eyes '. There is no fundamental difference between past and future so far as the calculation is concerned ; it is based upon a symmetrical, reversible relation. In other words, what

[1] It is not necessary, for the sake of the illustration, to take into account any technical difficulties in giving precise significance to the chronological dates.

we commonly understand by the passage of time has been eliminated, for temporal passage is intrinsically irreversible.

This must not be taken as meaning that for the supreme intelligence past, future, and present are on the same footing. He is a Calculator. He calculates from *something given* (present) to *something not given* (past or future). We may take present as *here* ; past as *somewhere out of sight on one side*, future as *somewhere out of sight on the other side*. Using this language we may say that the Calculator by seeing what is going on *here* can calculate what is going on *there* on either side, however far away *there* may be. The point of insisting that *there* is out of sight is that, if the whole field of view were given, then it would always be possible for the Calculator to construct analytical functions, with any desired degree of approximation, that would connect any one part of the field with any other part. Thus the possibility that such functions could be constructed would not be sufficient to distinguish an orderly or deterministic world from a non-causal or chaotic world. Such an interpretation would reduce the formula of Laplace's supreme intelligence to a barren tautology. What is required is the possibility of a formula that would yield a calculation concerning something not given.

Calculation of the kind we have been considering may be regarded as equivalent to prediction. By a convenient extension of the word, we may speak of predicting *backwards*, i.e. calculating that something of a certain sort did happen in the past, or, in other words, happened *there*. Prediction is extrapolation. It will be worth while to consider what is involved in extrapolation and interpolation. A very simple illustration will suffice for our purpose.

We will suppose that we are given the following array of dots



FIG. I

We are asked to connect them by drawing a continuous line through the dots, beginning with the first and ending with the last dot. We draw a line and obtain



FIG. II

The reader no doubt feels confident that the line thus drawn is *the* proper line to draw ; he is confident that it is the simplest line that fulfils the condition that *all* the dots must lie on the line. He recognizes the line as part of the circumference of a circle. But we might have drawn the line



FIG. III

or an indefinite number of other lines, each of which lines would have fulfilled the conditions.

Now, taking the dots to stand for terms which we are required to connect by means of a continuous function, we may regard the line drawn through the dots as a graphical representation of that function. We have *interpolated* other terms, and, in the case of Fig. II, we have assumed that, had we been given other terms they would have been representable by points on the circumference of a circle. We should be extrapolating if we were to complete the circle part of whose circumference is given in Fig. II, or if we were to continue the line in any other manner that would be in conformity with a formula that lays down a rule. I could not suggest any formula that would yield the queer curve in Fig. III. That is partly the reason why it seemed to me appropriate to say that it is a *queer* curve.[1]

If I see a batsman hit a cricket ball, and a very few seconds later I see the ball hit the roof of the pavilion opposite to me, I assume that the ball has traversed a series of intermediary positions, or in other words, that it has traversed a path in space, although I did not actually keep it under observation throughout the whole of its flight from the bat to the roof of the pavilion. It is natural to suppose that, if I knew the speed of the ball at the instant of its contact with the bat, the force with which the batsman hit it, the mass of the ball, the angle of its incidence and rebound, I could completely describe the path traversed and could also say at what place the ball would have reached the ground, had there been no pavilion in the way but only a wide level plain. To make this supposition is to suppose that the ball

[1] It is not possible here to go fully into the interesting problem of *queerness*, nor to discuss what is meant by " simplicity " when we speak of ' simple curves ' and ' simple laws '.

follows a path that is determined in accordance with ascertainable physical laws.

No doubt many an enthusiastic watcher of cricket matches, ignorant of mechanics, may have exclaimed—as he sees his favourite batsman strike a ball—'Oh! a catch!' His fears may be justified *in the event.* He has then made a prediction, and, unfortunately for the cricketer, a true prediction. He has, in other words, *foreseen* what was going to happen but had not yet happened. Prediction is extrapolation in accordance with a rule (or formula) derived from the discovery that certain observed happenings are connected in a regular manner.[1]

It is important to be clear with regard to the conditions that render an event predictable. They are the same as the conditions that enable us to *apply* a physical law. As an example we may take the firing of a shell from a gun. If we neglect the resistance of the air, we can say that the path of the shell, i.e. its trajectory, is a parabola. The path traversed by the shell is determined by certain laws. To define a path two points at least are required. To be able to ascertain what path the shell will follow it is necessary to know the direction in which the barrel of the gun is pointing when the shell is fired, and the velocity of the shell as it leaves the muzzle. If we know these, we are said to know *the initial conditions.* If we know the initial conditions, and if we also know the relevant physical laws, we shall be able to predict what path the shell will traverse, and at what place it will strike the earth. In the statement of a physical law nothing is said about initial conditions, for a law is not a

[1] It is not, of course, enough that the observed happenings should be capable of being connected by means of a mathematical function; there must be extrapolation (or interpolation) to what has not been observed.

statement about a particular occasion. But physical laws can be *applied* to particular occasions. It is a condition of such application that the initial conditions should be known. The construction of bridges and aeroplanes is the result of such application of physical laws. When we predict, we apply laws of nature.

It is easy to see that prediction of this sort—which we may call physical prediction—is utterly different from clairvoyance. Not any sort of foretelling the future or of divining the past can be regarded as physical prediction. Whether or not clairvoyants, or any other kind of prophets, can give us true information concerning what will happen does not here interest us. The physicist has, I presume, no wish to be a prophet; in so far as he wishes to predict, he does so in order that the predicted happening may verify his theory. He extrapolates from a physical formula in order that the values thus computed may be tested by reference to what is actually observed but did not form part of the data by reference to which the formula was derived.

The spectator at the cricket match, referred to above, who foresaw that the batsman had hit up a catch, cannot be said to have made a physical prediction. No doubt he would have said, if questioned, that he 'knew in his bones' that *that* was a catch. In this case (as in the case of some Cambridge philosophers) his 'bones knew' a good deal, for it was necessary not only that a fielder should be at the right spot but also that he should not muff the catch. Of course, he might have muffed it, or the ball might really have fallen just beyond his utmost reach, even though to the spectator it seemed that it *must* fall just there. Certainly, if the catch had been missed, the spectator would not have felt that anything had 'gone wrong' with the laws of nature. He would admit that he had made a mistake. He was not

concerned to make a physical prediction ; also, he was presumed to be ignorant of mechanics. Even if, contrary to our original assumption, the spectator had been a competent physicist, his remark would not have been a physical prediction. Nevertheless, there is an important respect in which the remark, 'Oh! a catch!' resembles physical prediction and is utterly different from the foretelling of a clairvoyant. It is worth while to pursue this resemblance and difference a little further.

The prophesying of a clairvoyant is, so I understand, professedly independent of past experience ; it is in no sense based upon knowledge concerning the past behaviour or the present circumstances of the persons and things about which the prophesy is made. The clairvoyant cannot say *how* he foretells, or, if he does give any account, it is not an account that will enable other people to go and prophesy likewise. In short, the clairvoyant's prophesy is not, and is not meant to be, *rational* foretelling. Quite the contrary is the case. But physical prediction is rational. It is rational in that it is based upon experience of what has happened, and the formula in accordance with which the prediction is made can be stated in a way that is intelligible to other people. The distinction between physical prediction and other rational predictions is that a physical prediction permits of being tested by measurements. The cricket enthusiast's foretelling of the catch resembles physical prediction in that it is based upon past experience of the behaviour of cricket balls, batsmen and fielders ; it differs from physical prediction in that it is not explicitly in accordance with a formula and is not so formulated as to admit of verification by measurement. No doubt he could explain to some one else the sort of way in which his judgement was made, but it might be the case that he could not do so. His skill in making such judge-

ments is certainly not dependent upon his ability to explain them, for this ability would depend upon his articulateness and his power of analysing the processes involved.

This discussion has not been a digression. It is important to understand what is meant by scientific determinism, what is the evidence (if any) for it, and where (if anywhere) determinism is found. As Eddington has pointed out, there could be no science unless there were recurrencies in sensory experience. The common reader counts upon these recurrencies and guides his practical activities by his knowledge of them. He expects a piece of paper to light if he holds it in a flame ; he expects a lump of sugar to melt when he has dropped it into a cup of hot coffee ; he expects a train to leave Euston at approximately the time stated in Bradshaw ; he expects to obtain milk from a cow (under certain easily statable conditions). He expects these things to happen because they do in fact happen. Unless there were regularities of such sorts, ' expectation ' would be a word devoid of meaning. When a given expectation is not fulfilled, we expect that something else has happened that prevented the fulfilment ; we then suppose that this expectation was not based upon sufficient knowledge of the situation. Expectations are confined to a limited range of happenings. An expectation is implicitly an answer to a question with regard to this or that recognizable aspect of what is experienced, or with regard to all aspects of a certain sort capable of being definitely described. In order that physics as a science should be possible, it is necessary that we should be able to consider some characteristics in isolation from other characteristics. It is in fact the case that physicists have been successful in regarding the physical world as separable into small systems, and into sub-systems of those systems, with respect to which physical statements can be made. It may be true that

Thou canst not stir a flower
Without troubling of a star,

but it must be admitted that no one stirring a flower has ever succeeded in observing the consequent troubling of a star. Astronomers have prosecuted their researches in the confident belief that in turning their telescopes upon the moon they have in no way affected that which they are observing. If the moon has been unaffected by their attention to it, so much more the stars. At the same time, they believed with the poet—to whom indeed they had presented the notion—that the picking of a flower or the winking of an eyelid on this earth affects the stars in their courses. This stupendous faith far outran the facts. We believe the poet's statement (suitably translated into scientific language) because it is a logical consequence of the principles of mechanics. We do not believe it because we believe that it would ever be possible for anyone to *observe* the movement of the star consequent upon the moving of the flower. Our reasons for believing in this consequent movement are derived from our belief in the principles of mechanics. Our belief in these principles is originally based upon our observations of bodies moving upon the earth. It was assumed that these observations could be made without taking note of the movement of the fixed stars.[1] We should not be able to resolve any problem, and thus the physical sciences could not have originated, had we not been able successfully to assume that there are isolated physical systems. Later we can go on to say that these systems are only relatively isolated, and that a completely isolated system is a convenient fiction.

Consider the following example. A thin piece of copper wire is set up in a laboratory. An electric current is passed through the wire. The strength of the current is known,

[1] Cf. C. D. Broad: *Scientific Thought*, pp. 107 *seq.*

also the resistivity of the copper wire. The amount of resistance generated in the copper wire can then be predicted.[1] The system thus set up can be regarded as relatively isolated; that is to say, changes occurring in this system can be considered in independence of changes occurring elsewhere. The system consists of: the source of the current, the copper wire (i.e. the conductor through which the current flows), and the ammeter that measures the strength of the current. As the current flows through the wire, the temperature rises. A physical law is a statement that certain changes in a system are connected with certain other changes in that system in such a manner that extrapolation is possible. It is a distinguishing characteristic of a physical law that it is concerned with measurable elements.

Physical laws can be used for the purposes of prediction. In thus using a physical law we are applying it to what actually happens. Given that we know the initial state of a system and a physical law connecting changes of states, we can predict the result of any measurement at any moment, preceding or subsequent. This is, indeed, what Laplace's Calculator is supposed to know with regard to the *whole* physical universe, and not only with regard to systems that are taken to be relatively isolated—i.e. relative to the questions that are to be asked about the system.

This form of reasoning can be summed up in the statement: If the initial state of a system and the laws of its behaviour are known, then its states at any other moment can be predicted, and the prediction can be verified by measurement. Any science which is wholly based upon such reasoning may be said to be a physically determined system, and its 'scheme of law' (to use Eddington's phrase)

[1] See my *Modern Introduction to Logic*, Chap. XIII, § 4; Chap. XVII, § 2.

is a deterministic scheme of law. The theories of classical physics provide an example of such a deterministic scheme. It was assumed that such errors as occurred were due to deficiencies in the instrument of observation or in the skill of the observer or in his ignorance concerning some relevant factor, *which ignorance was remediable.* That is to say, it was assumed that it was possible, in principle, wholly to eliminate the sources of error and precisely to determine the initial conditions. It is this assumption that has had to be surrendered. The development of quantum theory has shown that in the case of sub-atomic phenomena it is in principle impossible to determine precisely the initial conditions. This is a fact of cardinal importance from the point of view of the Laplacean ideal.

Those who believe that the development of physics during the twentieth century has an important bearing upon the 'problem of free will' have laid stress, first, upon Niels Bohr's theory of admissible quantum orbits; secondly upon Heisenberg's Principle of Uncertainty, somewhat unfortunately named by Eddington 'the Principle of Indeterminacy'. Some attempt must be made to indicate briefly the main lines of development in so far as they bear upon the rejection of determinism. For a fuller account the reader must refer to one or more of the books mentioned in the bibliography.

Max Planck—'the founder', says Eddington, 'of the physical theory that has led to the present crisis'—initiated this theory by his discovery of what is now called Planck's constant, represented by *h*. This constant plays an important part in the developments with which we are concerned. It must suffice here to recall that modern theories with regard to the structure of the atom are based upon the investigation of frequencies of radiation. A luminous body emits energy

in the form of radiations. In the wide sense in which the word 'light' is now used in physics, light comprises all electromagnetic radiations. Visible light, i.e. the visible spectrum, constitutes only a very small part of the scale of these radiations. In the course of his investigations of black body radiation Planck discovered that radiant energy is emitted and absorbed by definite amounts, and that there is a minimum quantity of energy just as there is a minimum quantity of matter. This minimum quantity is called a quantum of energy. These energy quanta are different in the case of each different wave-length. If ε is the energy of a vibration, and ν is its frequency, then

$$\varepsilon = \nu h$$

where h is Planck's constant. Thus the energy divided by the frequency is h, or $2h$, or $3h$, or some integral multiple of h.[1] Einstein, accepting Planck's theory, suggested that light itself consists of quanta, i.e. small bundles of energy, now called photons. Thus light is atomic.[2]

Since the time of the ancient Greeks there have been people who believed that a material body, e.g., a piece of wood, or a herring, is composed of atoms, i.e. discrete entities, conceived as very tiny, absolutely hard bodies. In the nineteenth century this theory was developed in a scientific manner; its development yielded what has been called 'the billiard ball view' of the physical universe. Thus matter is now recognized to be atomic, that is, discontinuous in character. A quantity of hydrogen, say, enclosed in a vessel contains a definite number of atoms of hydrogen; this amount cannot be increased or decreased by half an atom

[1] The numerical value of h is $6{\cdot}55 \times 10^{-27}$ erg. secs.; its dimensions are those of 'action', i.e. energy × time.

[2] An electric power station, for instance, can supply any amount of energy, but it cannot split a charge of $1{\cdot}6 \times 10^{-19}$ coulomb.

but only by an integral number of atoms. Probably few people find it difficult to imagine that atoms are in turn capable of being broken down into electrons and protons. Indeed, there is rather a danger of our picturing much too easily the electronic structure of matter. The danger lies in the fact that the picture is apt to be modelled upon the behaviour and appearance of things in our every-day experiences, and thus the elements in the model come to be regarded as having the properties of these things. Moreover, to the extent to which the picture has been imaginatively realized, it is apt to control our thinking in a misleading manner. One danger is that we come to think of everyday things, e.g. a table, as built up out of the elements appearing in the model much in the way in which a house is built up out of bricks. We have seen how easily people tend to transfer the properties of macroscopic bodies to electrons and protons, and how difficult it is to realize and keep steadily in view the fact that macroscopic language is inadequate for the purpose of describing microphysical entities. This being so, it is perhaps fortunate that when we are called upon to consider atoms of energy pictures fail us. Planck's discovery of quanta was certainly revolutionary in that the conceptions involved in the theories that have been developed upon the basis of this discovery do not even seem to be capable of statement in the language appropriate to macroscopic bodies.

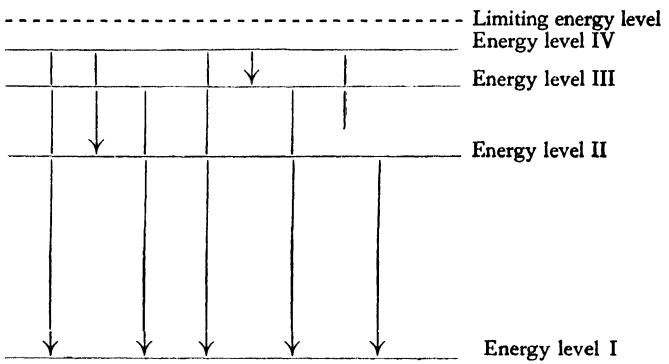
Planck's quantum principle was not recognized as one of the most fundamental of physical laws until Niels Bohr used it to elucidate the nature of the atom, and thereby explained the significance of spectrum analysis. It has been said that spectra are the language of atoms. Perhaps we may say that Bohr first made the language intelligible. The way in which his theory interpreted the Balmer and Lyman series forms a most exciting chapter in modern physics, of very

great interest to the methodologist. It is not, however, possible, nor indeed necessary, to follow these developments here. The reader who is familiar with this development may perhaps marvel that Eddington should have been content to present modern developments in physics as tending to the discovery that 'Something unknown is doing we don't know what'. It must suffice now to remind the reader that Bohr's theory of the structure of the atom was based upon Rutherford's conception of the atom as consisting of a small positive charge of electricity (the nucleus) surrounded by a number of electrons. The nucleus is regarded as taking the position of the sun with the electrons as planets revolving round it.[1] This planetary theory of the atom encountered various difficulties. According to the principles of classical mechanics the energy of an atom ought gradually to decrease; in other words, the electron ought gradually to slow down and, consequently, assume an orbit of ever decreasing radius. But the line spectrum gives a definite set of frequencies, not a continuous spectrum, such as would be the case had the frequencies differed continuously. Accordingly, Bohr assumed that some only of the geometrically possible orbits were physically admissible. This supposition involves a radical departure from classical ideas. This may be seen if we reflect that the earth, had its speed been slightly different from what it is, would have revolved in a slightly different orbit. But Bohr's supposition is that, in the case of the atom, a selection only of what might have been regarded as *possible* orbits were in fact *admissible*

[1] Bohr assumed that the orbits were circular. W. Wilson showed that there are elliptical orbits. The change to elliptical orbits and the discovery that there are more orbits than Bohr had supposed were due to the necessity of explaining the fine structure of the hydrogen spectrum.

orbits. These admissible orbits are those which are equal to h or to some integral multiple of h, if measured by the action. The electron revolving in one of these orbits is said to be in a *stationary* state, since its energy is constant. When an electron emits or absorbs energy it may be said 'to jump' from one orbit to another. If it passes from a lower level (smaller orbit) to a higher level (larger orbit), it absorbs energy; if it passes from a higher to a lower level it loses energy, that is, it emits radiation.[1]

A diagram may make this point clear.



An electron may jump from any higher to any lower level, but there can be no jump from an intermediate position. An illustrative metaphor may be derived from considering a swimming-bath in which there are, say, six different planks, or steps, from which a diver may dive into the water. He can, in principle, choose any one of these levels from which to dive, but he cannot (so long as he keeps to the recognized diving places) jump from any intermediate position. These recognized positions correspond to the admissible orbits to each of which an energy level corre-

[1] It is action that is quantized; energy is conserved.

sponds. In the lowest energy level (corresponding to the smallest orbit) the atom is in an extremely stable state ; it can change its level only by going higher, for which purpose there must be collision with another electron. With this we shall not need to be concerned. The illustration of the diving boards is defective in a very important respect, namely, that the divers always 'jump' from the step to the lowest level, viz. the water ; whereas in the case of the electron the jump may be from level IV to III, or to II, or to I, and from III to II, or to I, and so on. But having started, it must reach the next level. That is, a complete step must be taken. In changing from a higher to a lower level, radiation is emitted, i.e. light of a definite wave-length. This is observable and measurable ; it affords the only knowledge that we have that a jump has occurred. Bohr's theory explains (up to a point) the lines in spectra of atoms having a single electron. It is concerned with individual atoms. But spectral lines differ also in intensity. It may be assumed that the more intense the line (corresponding to a definite wave-length), the greater the number of electrons which make a particular jump.

At this point two questions may be asked, which are of importance for the topic of this chapter. (1) Is it possible to predict when an electron will jump from one orbit to another, and to which orbit it will jump ? (2) How many atoms of a given aggregation of atoms (say, in a gas) will make a particular jump ? It is in the answers given to these questions that Bohr's theory effects a radical break with classical physics.

The answer to the first question is that such a prediction is not possible. That is, given that the electron is at energy level IV (i.e. is revolving in orbit IV), then it is not possible to predict when it will change to another level, nor, if it

does change, to which level it will pass. Suppose, however, that an electron has jumped from IV to I; then its initial state and its final state are known; from this knowledge it is possible to deduce that it will emit a particular wave-length (i.e. a particular line of the Lyman series). Thus the deduction is from a knowledge of the initial *and* final states; there is no prediction from a knowledge of the initial state to a final state. Accordingly, it is said that the jump is not *determined*, since it cannot be predicted.

The answer to the second question is that a certain percentage of electrons will pass from one energy level to another, and a different percentage from another energy level to yet some other level. It follows, then, from Bohr's theory that the behaviour of an individual atom is not determined in accordance with any known laws. To say that its behaviour is not determined is to say that there are no means by which how it will behave may be predicted. Given a large number of atoms, then their behaviour is in accordance with ascertainable laws. These laws are statistical.

It is important to notice that this theory involves a complete break with the deterministic scheme of law of classical physics. It is true that Bohr's theory of atomic structure includes a considerable admixture of classical conceptions, since it involves the conception of electron orbits, of electron velocities, and of the relative phases of electronic orbits. This admixture is, however, a defect and soon led to a conflict with the experimental evidence. Subsequent progress has been in the direction of elaborating theories that depart more and more from classical conceptions. But even in its first form Bohr's theory necessitated a break with classical theories and provided the first set of arguments in favour of indeterminism.

The use of statistical laws is by no means new in physics. Such laws have been used in connexion with the kinetic theory of matter since the time of Clerk Maxwell. A statistical law is based upon the behaviour of a large number of individuals. A gas is composed of a vast number of molecules moving very rapidly in all directions, constantly colliding with one another and altering their directions. It is not in practice possible to determine the velocity or the path of an individual molecule. All that can be done is to say what is the average velocity and what path, on the average, is followed between one collision and the next. It is, however, assumed that the movement of each molecule, that is, its velocity and path, does in fact take place in accordance with definite laws ; in short, that the movement is causally determined. Thus, although only statistical laws can be applied, it is held that these laws are based upon causal laws. It is assumed that it is not absurd to suppose that, could we ascertain the initial conditions of a molecule's movement, we could predict where exactly it would be at a later moment. Hence, the use of statistical laws in the kinetic theory of matter did not involve any conflict with the Laplacean ideal.

The case is otherwise with the electron jumps of Bohr's theory. There is no way of discovering when an electron will jump, nor to which orbit it will jump. The initial state does not determine the final state ; hence, the final state is unpredictable. It is unfortunate that this unpredictability has often been expressed by saying that the electron is ' free to choose ' where it will jump. Such language is wholly inappropriate and has led to much confusion in discussions concerning the bearing of recent developments in physics upon the problem of free will.

Those who desire to safeguard human freedom from the

encroachments of science have lately laid much stress upon the Principle of Uncertainty, formulated by W. Heisenberg in 1927. According to Bohr's theory, it is necessary to regard an electron as now here, now there, in the course of its orbital motion. That is to say, an electron was regarded as having a definite position and a time of revolution. What is observed, however, are the frequencies of the light emitted by the electron; in its steady state the electron could not possibly be observed, but only when in changing its state radiation is emitted. Since every physical entity must be measurable, the question arises: How is the position or the velocity of an electron to be measured? It was in the attempt to answer this question that Heisenberg's Principle of Uncertainty was obtained.

In several popular expositions of this Principle stress is laid upon the difficulties we encounter in the attempt to *see* an electron.[1] Nothing can be seen in the dark. Consequently an electron must be illuminated if we wish to see where it is. But an electron has dimensions very much smaller than a light wave of the shortest visible light. Hence, in the sense in which one of the minute infusoria may be 'seen' through a microscope, an electron cannot be seen. This 'unseeability' of an electron is not the result of any defect in the construction of microscopes, which might 'ideally'—to use Eddington's word—be overcome. It is the result of the corpuscular structure of light. Hence, it is not in principle remediable. It is obviously impossible to see a body that is smaller than the wave-lengths of the light by which it is illuminated. The shortest wave-length in the visible spectrum is violet; it is of the order of hundred-thousandths of a centimetre. In the domain of microphysics this is an enormous amount. The dimensions of the atom

[1] See, for instance, Eddington's account in *N.Ph.W.*, pp. 223 *seq.*

considered in Bohr's planetary model is many thousands of times smaller than the wave-length of violet light. An electron, it will be remembered, is a very minute planet in this system of the atom.

I think that it is misleading to speak of 'seeing' an electron, unless the statement be regarded explicitly as metaphorical. Let it be granted, however, that there is a sense of "see" in which any body, however small, could be 'seen' provided that it were illuminated with radiation of smaller wave-length than the dimension of the body in question. In that case, in order that the electron should be seen, the radiation used would have to be of very short wave-length. That is equivalent to saying that the radiation would consist of photons of very great energy. It would in fact be necessary to use gamma-rays.[1] There would then be a Compton effect, i.e. the momentum of the electron would be altered by the impact upon it of a photon, for the photon loses part of its energy to the electron. Thus the electron gains in energy, i.e. its momentum is increased, and the greater becomes the uncertainty about its direction. On the other hand, the measurement of momentum would be ascertained by the Doppler effect, using long waves, that is, it would be ascertained by the alteration of wave-length undergone by the illuminating rays during reflection by the moving electron. To reduce the error concerning momentum the longest possible waves must be used in order to reduce as much as possible the unavoidable Compton effect. But an accurate determination of the position of the electron can be made only with short waves. Accordingly, the more accurately the position is ascertained, the greater is the uncertainty as to its momentum; the more accurately

[1] The wave-length of hard γ-rays is not greater than 11^{-10} cm., the normal radius of the hydrogen atom is about $5 \cdot 10^{-9}$ cm.

the momentum is ascertained, the greater is the uncertainty in the position. Thus, it is not possible to ascertain with complete accuracy both the momentum and the position. The more accurately the one is ascertained the more inaccurately is the other ascertained. This 'more' admits of precise statement, and is precisely stated in Heisenberg's Principle of Uncertainty. This Principle states that the product of the uncertainty of position and the uncertainty of momentum is never less than Planck's constant *h*. The amount of uncertainty in the one is correlated with the amount of uncertainty in the other, but it is not possible to reduce either uncertainty to zero. We might formulate the Principle of Uncertainty as follows:

> *Mass of electron* × *error in measurement of position* × *error in measurement of velocity is of the order of magnitude of* h.

There are other quantities besides momentum and position that cannot be simultaneously measured with complete accuracy. Quantities of this kind, which go in pairs, are called *conjugates*. To decrease the uncertainty in the measurement of one is to increase the uncertainty in the measurement of the other.

It is important[1] to emphasize that these uncertainty relations are in no sense dependent upon defects on the part of the observer or of his instruments of measurement. They are wholly due to the fact that some means of measuring must be used, and the means of measuring affects what is to be measured. Bohr has pointed out that there is a similar situation in the investigation of mental states. The more accurately a man tries to determine the anger he is feeling, the less does he experience the anger he originally

[1] 'Important' because many philosophers have supposed the contrary.

tried to assess. But it must be remembered that it is misleading to say that 'looking at' the electron affects its momentum ; it is *illuminating* it that has this effect. There is interaction between the instrument of measurement and that which is measured. Every measurement tells us something about the relation of that which is measured to that which measures it. Planck's constant sets a natural limit to the accuracy of physical measurement.

Once the Principle of Uncertainty is accepted—and it must be accepted—then we must admit that it is not possible, even in principle, to know the initial conditions in the case of quantum phenomena. Hence, unless he confines himself to non-quantum phenomena, Laplace's Supreme Intelligence is not able to begin his calculations, since he cannot know precisely the initial conditions. Accordingly, he has no bases from which he can set out. The classical deterministic system was based upon the assumption that the initial conditions can be precisely known. This is true with regard to macroscopic phenomena, as, for example, in the case of firing a shell from a gun. The trajectory can, in principle, be predicted with any degree of accuracy. It was natural to suppose that, since astronomers can predict eclipses of the moon with extreme accuracy, such predictions were theoretically possible in the case of microphysical systems. But the development of quantum mechanics has shown that no precise meaning can be given to the combination of momentum and position as simultaneously ascertainable in the case of an electron. The conceptions of space and time, as they appear in classical physics, do not apply in the domain of microphysics. In classical physics, however, they are fundamental notions.

The upshot of the acceptance of the Principle of Uncertainty is the admission that the basis of quantum laws is

statistical, so that the conception of causal laws ceases to have application. Further, it takes away any reasons there may have been for regarding the material universe as a huge machine. The machine-picture has never been worked out in detail; but the *ideal* of a machine has been imaginatively grasped by physicists and, in consequence, language appropriate to the behaviour of machines has been very extensively used. The rejection of this machine-language is an important gain. It makes for clearer thinking with regard to the philosophical implications of physics. There is, however, a danger that we may reject the language whilst we continue to be influenced in our thinking by the machine-image. We need also to avoid the not uncommon mistake of supposing that the uncertainty relations show that there is anything *indeterminate* in Nature, or that science has now had to become inaccurate. Yet this is what Jeans seems to suppose. 'Heisenberg now makes it appear', he says, 'that nature abhors accuracy and precision above all things.' This is surely an absurd mistake. Granted that, in a given case, the initial conditions are determined as precisely as the Principle of Uncertainty permits, then the probability of all subsequent states is determined by *exact laws*. Given that the experiment is repeated a great many times, then it is possible to predict both the frequency of occurrence of the expected effects and the deviations from these effects.[1] There is nothing *lawless* in quantum phenomena.

[1] Dirac has said, 'When an observation is made on any atomic system that has been prepared in a given way and is thus in a given state, the result will not in general be determinate, i.e. if the experiment is repeated several times under identical conditions several different results may be obtained. If the experiment is repeated a large number of times it will be found that each result will be obtained a definite fraction of the total number of times, so that one can say that there is a definite probability of its being obtained any time the experiment

Although I think that there is nothing lawless about quantum phenomena—and, if there were, then quantum phenomena could not be studied by physicists—I wish to insist that the discovery of the uncertainty relations does involve a considerable change in our attitude to determinism. But I doubt whether it is quite the change that either Jeans or Eddington supposes ; nor do I think that it has just those philosophical consequences that these distinguished scientists imagine.

is performed. This probability the theory enables one to calculate. In special cases this probability may be unity, and the result of the experiment is then quite determinate.'—*The Principles of Quantum Mechanics*, 1930, 1st ed., p. 10.

Chapter IX

REACTIONS AND CONSEQUENCES

I do not think that there is any serious division of opinion as to the decease of determinism. If there is a division among scientists it is between the mourners and the jubilants. The mourners naturally hope that determinism will one day be re-established in its old position in physics ; that is possible, but I see no reason to expect that it will return in any shape or form.'

A. S. EDDINGTON

THE reactions of different thinkers to the rejection of determinism are both interesting and instructive owing to their extreme diversity and vigour. The extent to which the climate of opinion has been affected by the Laplacean ideal of the predictability of natural events is evidenced in the intensity of feeling displayed by scientists in drawing conclusions from the rejection of this ideal or in refusing to regard withdrawal from the standpoint of Laplace as more than a temporary expedient. Eddington seems to me to be right in saying that the division among the scientists is between the mourners and the jubilants. This description is apt. Some scientists passionately desire to retain strict causality or at least hope for its future reintroduction into the physical scheme. Some are delighted by the rejection and are hopefully confident that determinism has been shown to be a mere blunder, or at best, an illusion that has not been without its uses in the past. Some, perhaps,

are neither downcast nor elated, having no axe to grind; these do not concern themselves with the philosophical implications of physics. In this chapter we shall be concerned first with those who have axes to grind. We shall then raise the question what bearing (if any) the rejection of determinism has upon the problem of human freedom.

Max Planck would be among the mourners were it not that he steadfastly refuses to mourn. He sees no cause for mourning since he does not admit that determinism is dead. The developments in quantum physics necessitate, he admits, 'some essential modification' in the formulation of fundamental physical laws. At the same time he protests: 'I firmly believe, in company with most physicists, that the quantum hypothesis will eventually find its exact expression in certain equations which will be a more exact formulation of the law of causality'.[1] This statement merits, I think, Eddington's caustic comment: 'Thus the causal law is to be found, not in the quantum theory as it is, but in what Planck believes that it will eventually become' (*N.P.Sc.* 300). But the statement itself does not, I think, adequately present Planck's view, nor does it, together with Eddington's comment, make clear the point at issue between them. It is worth while trying to get clear concerning this point, since it is the origin of the line separating those that mourn from those that are jubilant.

The physicist as such (i.e. in so far as he is engaged in physical research) is concerned to establish a rational correlation of natural happenings. We saw in the last chapter that the ability to predict what happens has come to be regarded as the criterion of a satisfactory physical theory. The ideal of the physicist has for long been the attainment of such knowledge as Laplace attributed to the Supreme Intelli-

[1] *Where is Science Going?*, p. 143.

gence. This ideal presupposes universal strict causality, i.e. everything is determined to happen as it does happen and not otherwise. This is the ideal that has been abandoned. Eddington is jubilant at its downfall. Planck retains the ideal, but he does so only by redefining " event," and by insisting upon an extremely sharp distinction between ' the world-picture ', which it is the aim of physicists to formulate, and ' the world of sense '. He says that ' an event is causally conditioned if it can be foretold with certainty '.[1] But a physical event can never be predicted with complete accuracy. Moreover, the introduction of wave functions has profoundly modified the classical world-picture. But the wave functions belong, Planck maintains, to the world-picture, not to the world of sense. Accordingly, there is no need to reject strict causality if we recognize that ' by an event, physics means a certain merely intellectual process '. Physics substitutes the construction resulting from this intellectual process for the world of sense that is the starting point of physics. He maintains that ' there is fully as rigid a determinism in the world-picture of quantum physics as in that of classical physics '. The inaccuracy arises in the transfer of the symbols of the world-picture to the sense-world, and conversely. Thus, on Planck's view, ' The uncertainty in forecasting events in the world of the senses disappears and in its place we have an uncertainty with regard to the connexion between the world-picture and the world of the senses. In other words, we have the inaccuracy arising from a transfer of the symbols of the world-picture to the sense-world, and vice versa '. He sees that such an inaccuracy is inconvenient, but he argues that the fact that

[1] *The Philosophy of Physics*, p. 45. Subsequent quotations in this paragraph are from the same Chapter. Cf. ' The Concept of Causality,' Planck's Guthrie Lecture, *Proc. Physical Society*, 1932.

physicists are willing to put up with it affords 'an impressive demonstration of the importance of maintaining the rule of determinism within the world-picture'. He has apparently failed to remember[1] that many physicists are not willing to put up with it, nor do they find any need to do so since they are only too glad to banish determinism from the world-picture in order to banish it also from the world of sense. Planck is as firmly convinced that science is based upon a law of strict causality as Eddington is that 'so far as we have yet gone in our probing of the material universe, we find no evidence in favour of determinism'.[2] They are, however, agreed that 'the validity of the law of causation for the world of reality is a question that cannot be decided on grounds of abstract reasoning'. This statement is Planck's,[3] but Eddington has enthusiastically endorsed it. But closer examination shows that the agreement is not so profound as Eddington's welcoming of it would suggest. For Eddington supposes Planck to have admitted that there is *no reason* for accepting the law of causality whilst nonetheless professing his own faith in it. This is not how I should interpret Planck's contentions. On the contrary, I think, he wishes to maintain that, whilst there is no *logical* contradiction in the notion of an uncaused event, yet the aim of science cannot be achieved unless events are causally connected in a strict manner. The law of causality is a presupposition of science. The two following statements bear out this interpretation of Planck:

Of course it may be said that the law of causality is only after all

[1] Although, of course, he has frequently had occasion to note their entire willingness to surrender determinism. His recent writings are a sustained polemic against 'indeterminists' and 'positivists'.

[2] *Science and Religion*, p. 125

[3] See *Where is Science Going?*, p. 113, and cf. *N.P.Sc.* 298.

an hypothesis. If it be an hypothesis it is not an hypothesis like most of the others, but it is a fundamental hypothesis because it is the postulate which is necessary to give sense and meaning to the application of all hypotheses in scientific research. This is because any hypothesis which indicates a definite rule presupposes the validity of the principle of causation.[1]

It is true that the law of causality cannot be demonstrated any more than it can be logically refuted : it is neither correct nor incorrect ; it is a heuristic principle ; it points the way, and in my opinion it is the most valuable pointer we possess in order to find a path through the confusion of events, and in order to know in what direction scientific investigation must proceed so that it shall reach useful results.[2]

This belief that the law of causality is a heuristic principle is responsible for Planck's conviction that quantum phenomena must eventually be brought under a causal scheme. He concedes, and indeed, even insists, that ' we cannot know how far the principle of causality is valid except by putting it to the test of outer reality '.[3] But it must, on the other hand, be noticed that Planck is unduly confident that eventually this test will be satisfied in all domains of knowledge. He is *unduly* confident because he has contented himself with the bare assertion that ' statistical laws are dependent upon the assumption of the strict law of causality functioning in each particular case ',[4] and has made no effort to examine the opposite view. Yet he must be aware of the fact that it is just this dependence of statistical laws upon causal laws that has been called in question by Heisenberg, Schroedinger, Jordan, Max Born, and others. To attempt to settle the question in this purely dogmatic manner is surely unsatisfactory.

I do not doubt that Planck's dogmatism has escaped his own notice, since it proceeds from his unquestioning

[1] *Ibid.*, p. 150. [2] *The Philosophy of Physics*, p. 76.
[3] *Where is Science Going ?*, p. 151. [4] *Ibid.*, p. 145.

adherence to the outworn Laplacean ideal of rationality.[1] This adherence is the source of his unrelenting opposition to any positivism in science. If science is rational, Planck seems to argue, then the world-picture of science must be a deterministic picture. In like manner, Bertrand Russell maintains: 'Determinism, whether universally true or not, is coextensive with the sphere of possible scientific knowledge; where it fails, scientific knowledge fails'.[2] Such a statement remains at the level of unwarrantable dogmatism unless it be shown in detail either *how* quantum phenomena exhibit deterministic law or that quantum physics does not fall within the sphere of scientific knowledge. No one accepts the second alternative; no one has succeeded in achieving the first. I venture to hope that Eddington, notwithstanding his delight in mystifying his readers by echoing Trinculo, is not in disagreement with the contention that scientific laws must be rational. This hope receives some confirmation from the concluding section of his latest work, *Relativity Theory of Protons and Electrons*. Commenting on the views he had formerly expressed, concerning the possibly irrational nature of the laws of quantum phenomena, he observes that these laws have now 'turned out to be rational'; he adds, 'Behaviour whose laws are irrational was perhaps as near to the conception of undetermined behaviour as the thought of the time could reach'. It is true—as we saw in an earlier chapter—that Eddington believes that the rationality is due to the fact that these laws have been 'imposed by the mind', but that consideration is not relevant to the present discussion.[3]

[1] Cf. *The Philosophy of Physics*, pp. 70–2.

[2] *Determinism and Physics* (Eighteenth Earl Grey Memorial Lecture), p. 18.

[3] On this point, see further, p. 279.

The main point at issue between Planck and Eddington is, then, not whether the scientist believes that his procedure is rational or whether this belief springs merely from an ungrounded faith ; it is whether a rational procedure must be based upon the assumption of deterministic laws. Planck says that it must be so based. Eddington says that it is not *now so based.* Although he is fond of calling attention to the modesty of this claim, he is not content with making it. Unfortunately he rashly adds that science does not offer a particle of evidence in favour of determinism. This statement surely requires some examination. For the purpose of such an examination it seems to me to be necessary to consider three closely connected questions. These questions are : (1) Is there any sense in which it is true to say that science has been based upon determinism ? ; (2) what is the connexion between determinism, prediction, and rationality ? ; (3) why should there be so much glee or so much gloom at the rejection of determinism ? Perhaps it does not seem obvious that these questions are closely connected, but I think it will be found by no means easy to disentangle them in the discussions of the scientists with whom we are mainly concerned.

(1) We have already seen that scientists have certainly *believed* that science was based upon determinism. Moreover, were that not the case there would have been no occasion for rejoicing or mourning, nor could we have spoken of 'the decline of determinism'. Indeed, Eddington insists that 'the withdrawal of physical science from an attitude it had adopted consistently for more than 200 years is not to be treated lightly' (*N.P.Sc.* 73). But to say that '*science* is based upon determinism' is to say that *scientists* have based their work upon determinism. There is no science apart from the minds of men. Accordingly, we can say loosely

that science is based upon determinism, provided that the procedure of scientists has been deterministic and that no alternative to this procedure can be consistently carried through. But, if it be true that 'so far as we have yet gone in our probing of the material universe, we find no evidence in favour of determinism', it must be concluded that the work of earlier scientists has been based upon an illusion. This is, indeed, what Eddington wishes to maintain. I think that there is a sense in which it is true, but to describe the acceptance of determinism as the acceptance of an illusion is, I believe, more misleading than helpful.

Eddington has himself pointed out a more satisfactory way of regarding the change from the old deterministic view. He says, in the passage immediately preceding the statement quoted above,

> The rejection of determinism is in no sense an abdication of scientific method. It is rather the fruition of a scientific method which has grown up under the shelter of the old causal method and has now been found to have a wider range. It has gradually increased the power and precision of the mathematical theory of observed phenomena.

This 'old causal method' Eddington calls 'the pursuit of primary law'. The method which grew up under its shelter he calls 'the pursuit of secondary law'. The former proceeds in accordance with the Laplacean ideal, namely, that what will happen is predetermined with certainty, i.e. is inevitable. The latter provides a method of predicting what will most probably happen. On the older view there were two types of natural law: 'The earth keeps revolving round the sun because it is impossible that it should run away. That is the primary or deterministic type. Heat flows from a hot body to a cold body because it is too improbable that it should flow the other way. That is the secondary or statistical type' (*N.P.Sc.* 80). Elsewhere Eddington says

that laws of the statistical type were regarded as 'stop-gaps representing the progress of knowledge in regions not yet fully connected with the scheme of primary law '.[1] Accordingly, these statistical laws were held to be reducible in principle, if not in practice, to causal laws. Now their position is reversed. The causal laws of classical mechanics and electromagnetism, which were regarded as the fundamental type of laws, are now recognized to be the limiting form assumed by the formulae of quantum theory in cases where very large numbers of quanta are concerned. This does involve a radical change of view. As we noticed in the last chapter, Maxwell used statistical laws, but his point of view was certainly determinist. His statistical methods were used for cases where it is not *practicable* to have all the data required for calculating an end result. In quantum theory statistical laws have an entirely different status. There is agreement between the new and the older view in holding that there cannot be a fundamental dualism—*two* types of radically different yet equally fundamental laws; there is, however, the important difference that, according to the new view, the fundamental laws are statistical, i.e. are acausal, whilst primary laws are special cases of statistical laws. This radical change in the status of statistical laws must not be forgotten.

Certainly most people find a difficulty in seeing *how* statistical laws can be fundamental. In the past we have often found that a statistical law is the sign that there is a causal law that had not yet been discovered. For example, it was discovered that there was a statistical law connecting working in a cutlery factory with a tendency to consump-

[1] Symposium on 'Indeterminacy and Indeterminism'. See *Aristotelian Society, Supplementary Vol. IX*, p. 165. Henceforth I shall refer to this paper as *Symposium*.

tion. Later it was discovered that the clogging of the lungs of the workers by fine particles of steel was the cause of the phthisical state. That is to say, in the case of each item in the statistical aggregate it was possible to trace a causal connexion. It is natural to suppose that this is always the case, and that statistical regularities are always dependent upon causal laws concerning the individual items. But what it is natural to think is by no means always correct. We easily suppose that what it is natural to think is also what it is rational to think. But that is by no means the case. It is natural for a rather stupid Londoner, who has never been abroad, to think that all pillar post-boxes must be red. He will discover his mistake if he goes to foreign countries. It is natural to think that dreams are chaotic in the sense that the dream imagery is wholly (or nearly completely) dissociated from the dreamer's waking life. Freud and Jung have shown that this is not so ; that what happens in dreams is causally dependent upon the experiences of the dreamer in his waking life. Accordingly, we ought not to conclude from the fact that it is natural to suppose that statistical laws cannot be fundamental, that in fact they are not fundamental. On the other hand, the fact that statistical laws have sometimes been shown to be signs of causal regularities makes it not unreasonable to suppose that, if we knew enough about the individual items, we should discover that this was always the case.

This point has been very clearly stated by Professor E. Schroedinger. In a lecture delivered in the year 1922, he says,

> Whence arises the widespread belief that the behaviour of molecules is determined by absolute causality, whence the conviction that the contrary is *unthinkable* ? Simply from the *custom*, inherited through thousands of years, of *thinking causally*, which makes the idea

of undetermined events, of absolute, primary casualness, seem complete nonsense, a *logical* absurdity.

But from what source was this habit of causal thinking derived? Why, from observing for hundreds and thousands of years precisely *those regularities* in the natural course of events, which in the light of our present knowledge, are most certainly *not governed by causality*; or at least not so governed essentially, since we now know them to be statistically regulated phenomena. Therewith this traditional habit of thinking loses its rational foundation.[1]

Schroedinger's answer to this question may be correct; perhaps our difficulty in seeing how statistical laws can be fundamental may be itself merely the result of our habit of 'thinking causally'. For my part, I must admit that I find it difficult to be convinced that this is all that there is to be said. What meaning are we to attach to 'absolute, primary casualness'? Does 'casual' simply mean 'non-causal'? Are we to understand by 'primary casualness' a 'mere random distribution'? But the random distribution must be logically prior to the statistical regularities. It is not easy to see what could be meant by a 'random' distribution in a lawless world. A non-random distribution is assumed to be more improbable than a random one, but it is not clear what are the grounds of this assumption.

[1] 'What is a Law of Nature?' published in an English translation in the volume entitled: *Science and the Human Temperament* (see p. 115). This lecture was given by Prof. Schroedinger, in Zürich, five years before Heisenberg formulated the Principle of Uncertainty. In this Lecture Schroedinger emphasizes the fact that Franz Exner had put forward, in 1919, 'a very acute philosophical criticism against the *taken-for-granted* manner in which the absolute determinism of molecular processes was accepted by everybody'. Schroedinger reports that Exner 'came to the conclusion that the assertion of determinism was certainly *possible*, yet by no means *necessary*, and when more closely examined *not at all very* probable'. This lecture seems to me one of the clearest that have been written on this topic.

It can hardly be that random distributions are known to occur much less frequently than non-random distributions, for this would require a much more extensive experience of observed frequencies than we have. Consider, for example, the oft-repeated assertion that, in a large number of throws of a penny, heads and tails turn up equally probably. It seems reasonable to suppose that, in asserting that the probability of a head turning up is one-half, we are either merely summarizing observed frequencies or are stating a rule from which predictions can be made. In the former case we have no basis for prediction; in the latter it seems to me that the premisses used must themselves be dependent upon a rule permitting the assertion of equiprobabilities.

Difficulties of this sort are not uncommonly felt. Although I feel them myself, I am not convinced that it is reasonable to do so; it may be only that I am unable to get rid of ancient prejudices. On the other hand, I think it may be reasonably urged that the assertion that statistical laws are fundamental does need to be backed up by some theory of probability. I do not know of any satisfactory theory of probability, and I am certainly not competent to produce one myself. At the same time, I think that there are difficulties, which ought to be faced by those who maintain a theory of 'absolute, primary casualness', in finding any criterion of 'primary casualness'.

I do not know to what extent Eddington would admit this. It is, however, interesting to notice that he admits the need for an *a priori* basis. He says:

> All probabilities rest on a basis of *a priori* probability, and we cannot say whether probabilities are large or small without having assumed such a basis. In agreeing to accept those of our calculated probabilities which are very high as virtually equivalent to certainties on the old

scheme, we are as it were making our adopted basis of *a priori* probability a constituent of the world-structure—adding to the world a kind of symbolic texture that cannot be expressed on the old scheme. (*N.Ph.W.* 305.)

Whatever difficulties there may be in finding a satisfactory basis for probability, no one doubts that an extremely high probability may be regarded as equivalent to a practical certainty. 'When the probabilities are large,' says Eddington, 'the substitution of probability for certainty makes little difference; it adds only a negligible haziness to the world' (*N.Ph.W.* 304). Since the 'haziness' is negligible, we may replace probability by certainty so far as practice is concerned. It is along these lines that the attempt is made to account for our very different attitude to well-established natural laws as contrasted with statistical generalizations, and to show how it is that it is possible to make very accurate predictions concerning the behaviour of macroscopic bodies. Thus Schroedinger says: 'In no case of a natural process is the number of single atoms which must co-operate in order that an observable effect may be produced so vast as in the case of gravitational phenomena. This would explain, from the statistical point of view, why we can attain such extraordinary accuracy in forecasting movements of the planets centuries ahead.' [1] This may be granted, but it still remains unclear how, on the basis of fundamental statistical laws, we are ever to be able reasonably to assert that in such and such cases there is a very high probability that so-and-so will happen.

It is sometimes asserted by those who are unwilling to reject determinism that laws concerning the behaviour of macroscopic bodies are indubitably deterministic. I am

[1] Op. cit., p. 117.

conscious of having a prejudice in favour of this view, but I am extremely doubtful whether it can be substantiated. There can, however, be no doubt at all that precise predictions concerning the behaviour of macroscopic bodies are made and are *exactly* verified within the limits of experimental error. The important consideration is that the verification is exact; in other words, extrapolation is possible. It is important not to confuse three entirely different statements: (i) This prediction can be exactly verified[1]; (ii) This prediction has a high probability of being true; (iii) This prediction is certainly true. It is now generally agreed that no statement of the form (iii) can be made in science. We may say that (iii) has been replaced by (ii). But (ii) has not replaced (i). Indeed, we may combine them and say, 'That this prediction can be exactly verified has a high probability of being true.' Statements of this form are sometimes true. When a prediction concerning a certain occurrence *has been* exactly verified, we can say that that occurrence was determined. In this sense the procedure of scientists has been based upon the assumption of determinism; that is, the deterministic method (to use Eddington's expression) has been constantly and successfully used. There is plenty of evidence in favour of determinism thus understood.

I think that the writers of popular science books have confused the common reader on this point. Eddington's discussion undoubtedly encourages such confusion. We have seen that he says that 'it is too improbable that the earth should run away from the sun'. To this statement he adds a footnote: '"Impossible" therefore disappears from our vocabulary except in the sense of involving a

[1] The *exactness* of a *verification* depends, of course, upon the degree of exactness attained in the prediction.

logical contradiction' (*N.P.Sc.* 80 *n.*). If this statement means that it is not logically impossible that the earth should run away from the sun, it must be admitted to be true. But this is no new discovery. Scientists might have learnt it from Hume; they might have gleaned it from the *Logic* of J. S. Mill; their attention was called to it by Jevons. Its upshot is to bring about the replacing of statement (iii) by statement (ii) above. There is no *logical* ground for maintaining that observed regularities in the past will continue into the future. But this fact has nothing to do with the possibility of the exact verification of a prediction concerning natural occurrences. Eddington seems to me to argue that the substitution of 'too improbable' for 'impossible' has been necessitated by the discovery of conjugates. But his argument from thermodynamics is, I think, independent of the Uncertainty Principle. The connexion is presumed to be that the heat laws are statistical and that the Uncertainty Principle has shown that quantum laws are statistical. But the improbability arising from the use of statistical laws is quite different from the improbability (or probability) that what has happened will continue to happen.

It has been argued that since macroscopic bodies are 'built-up' out of microscopic particles, what is true of the latter must be true of the former. But this, if not manifestly false (as I am inclined to think) is at least an entirely unwarranted assertion. To maintain it is to reverse the mistake made by nineteenth-century physicists who conceived atoms as billiard balls. Surely it is reasonable to suppose that the properties that it has been found profitable to isolate for the purpose of dealing with macroscopic bodies may not be capable of being imported into the study of microphysical entities, and that if an attempt is made to do

so, difficulties will arise. The fact that it is not possible in principle to observe the conjunction of momentum and position in the case of an electron might lead us to the conclusion that such a conjunction has no meaning. In one passage Eddington suggests this conclusion. He says :

> When we encounter unexpected obstacles in finding out something which we wish to know, there are two possible courses to take. It may be that the right course is to treat the obstacle as a spur to further efforts ; but there is a second possibility—that we have been trying to find something that does not exist. . . . From this point of view we assert that the description of the position and velocity of an electron beyond a limited number of places of decimals is an attempt to describe something that does not exist ; although curiously enough the description of position or of velocity if it had stood alone might have been allowable. (*N.Ph.W.* 221–2.)

He cites the attempt made to discover the earth's velocity relative to the aether as an example of an attempt to find what does not exist. But although he here draws a similar conclusion with regard to the conjunction of position and momentum of an electron, he does not seem to me to keep consistently to this conclusion. For he argues that, since the more accurately the one is known the less accurately the other is known, ' Nature thus provides that knowledge of one half of the world will ensure ignorance of the other half—ignorance which . . . may be remedied later when the same part of the world is contemplated retrospectively ' (*N.Ph.W.* 308). He thereupon urges, as Heisenberg also has done, that we must get rid of this unknowable element, just as we have got rid of the notion of velocity through the aether. Accordingly, he proceeds, ' This vast new unknowable element must likewise be swept out of the Present. Its proper place is in the Future because it will then no longer be unknowable. It has been put in prematurely as an anticipation of that which cannot be antici-

pated.' This argument assumes that only the present conjunction of momentum and position is unknowable, and, therefore, does not exist ; retrospectively an electron may have both. Surely this argument presupposes that it is not meaningless to speak of their present conjunction.

It seems to me that there are at least four logically possible alternatives that might be worth considering. Using q for the co-ordinate, or position, and p for the momentum, these alternatives may be stated as follows :

(1) The conjunction of p and q is accurately ascertainable.
(2) The conjunction of p and q is not accurately ascertainable.
(3) The conjunction of p and q has no meaning.
(4) The conjunction of p and q has meaning, but neither p nor q is a quantitative expression and cannot be used in connexion with the language of ordinary space and time.

Eddington's first statement, quoted above, suggests alternative (3). Heisenberg accepts (2) which, I think, implies the denial of (3). It is (1) that has been found to hold with regard to macroscopic bodies ; it is its failure with regard to electrons that has led to the acceptance of (2). I venture to suggest that both (3) and (4) are worth consideration. Both *position* and *momentum* are conceptions associated with our ordinary conceptions of space and of time, or with the conception of space-time derived from the theory of relativity. It may well be that no space or time conceptions are applicable to entities in the domain of microphysics. If this were so, then the attempt to use such conceptions would lead to insuperable difficulties. These difficulties might be avoided (as, it will be remembered, Eddington himself suggested) by the adoption of alternative (3). But alternative (4) does not seem to me

to be quite ruled out. Its acceptance involves a denial that space and time, in any ordinary sense, have significance in the microphysical domain, but this would, I suppose, be generally admitted. Positional and temporal co-ordinates have indeed become matrices.

The common reader must not forget that our ordinary conceptions of space and of time are associated with our everyday experiences of macroscopic bodies on this earth. We encounter only bodies that are very large compared with an electron, and velocities that are very small compared with the velocity of light or the velocity of an *a* particle. Relativity theory showed that, just as velocity is relative, so also position is relative to the frame of reference. This was surprising when it was first discovered but has now become a commonplace. Our expectations are based upon our commonplace experiences; that is why there are surprises in scientific discoveries. It does not seem, upon reflexion, that there is any difficulty in supposing that velocity and position are *jointly relative* to the measuring instrument. That would mean that alternative (4) must be accepted. But, no doubt, there are difficulties which I have not foreseen.

I do not think that for our purpose it matters very much which alternative we adopt. For our immediate purpose is to decide whether in the 'probing of the material universe', we have found any evidence in favour of determinism, and whether the 'abandonment of determinism' has any important consequences so far as human actions are concerned. Now it is important to notice that, since momentum is equal to mass multiplied by velocity, a definite variation in the momentum of a large mass will be associated with only a very small variation in the velocity. Accordingly, both can be simultaneously ascertained within the limits of

experimental error, i.e. as exactly as the experimental procedure permits. Thus an eclipse of the moon can be predicted with as much certainty as attaches to any statement that goes beyond what the observer is actually observing.[1] From the knowledge that the astronomer has of the momentum and position of this planet *now*, it is possible for him to predict its future momentum and position. Predictions of such a kind have often been shown to be true. The happenings thus predicted are predetermined. Science has developed because it has been found possible to make true predictions that are not clairvoyant prophesies. The scientists have *inferred* (not clairvoyantly foreseen) what will happen, and they have subsequently verified the prediction. The future has been anticipated only in the sense that extrapolations have been made and have been shown to be correct.

To sum up this long discussion. If the domain of undetermined happenings is the domain in which prediction is not possible, then science has been based upon determinism, and the work of scientists has provided much evidence in favour of determinism. If what happens is determined, then it must be predetermined. Here "must" signifies that predetermination is involved in the *meaning* of determination. I think Eddington is right in insisting upon this point.[2] If to say that an occurrence is predetermined means that the occurrence can be described wholly in terms of what

[1] In the case of the planet we cannot distinguish

$$\text{from} \quad \begin{matrix} \triangle p . \triangle q \sim h \\ \triangle p . \triangle q \sim o \end{matrix}$$

[2] See *N.P.Sc.* 76 : 'Determinism postulates not merely causes but *pre-existing* causes. Determinism means predetermination. Hence in any argument about determinism the dating of the alleged causes is all-important ; we must challenge them to produce their birth-certificates.'

has already happened, then we have knowledge of such predetermined events. For example, we do not need to wait until an eclipse has happened to predict that it will happen. Thus it is true to say that the work of the scientists has provided much evidence in favour of the belief that there are determined occurrences. On the other hand, it does not follow that all occurrences that can be dealt with by the methods of science are predetermined. It remains an open question whether there are any occurrences not wholly describable in terms of what has happened, and yet amenable to some scientific method. We ought not to accept too hastily Bertrand Russell's view that 'the sphere of possible scientific knowledge' is co-extensive with the domain of predetermined events. But it seems to me that, if there are undetermined occurrences, then predictions concerning them can be made only if large collections of such occurrences can be regarded in a deterministic manner. In such a case, statistical laws will be the *basis* from which the predictions proceed, but the predictions will be made in accordance with a deterministic procedure.

Eddington's manner of contrasting this procedure with the 'older causal method' seems to me to be confusing for the common reader. In speaking of the development of thermodynamics in the middle of the nineteenth century, he says: 'Whilst striving to perfect a system of law that would predict what *certainly* will happen, physicists also became interested in a system which predicts what *probably* will happen' (*N.P.Sc.* 76). Predicting, however, is a form of inference; inference is a form of thinking, in which a thinker starts from premisses and arrives at a conclusion. It is *we* who predict; to say that a law *predicts* is to talk nonsense (if the statement be taken strictly). Further, it is *events* (i.e. happenings in Nature or human actions) that

are predicted. We do not predict *laws*. To say that someone makes a prediction is to say that someone inferred (in accordance with a certain rule) that something will happen. To say that someone truly predicted something is to say both that someone inferred (in accordance with a certain rule) that something will happen and also that it did happen. To make a prediction it is necessary to have knowledge that a certain law (or set of laws) is certainly true or is probably true. It may be granted that no law of Nature is known to be certainly true. But from the *knowledge* that a given Law is probably true, we can infer that a particular occurrence *will probably happen*, i.e. infer that its happening has (such and such a degree of) probability.

I think that Eddington would challenge the statement I made above, namely, that predictions made upon the basis of statistical laws will be made in accordance with a deterministic procedure. There is, perhaps, a possible interpretation of this statement which would make it highly disputable, and to assert it in this sense would be to beg the point in question. This would be so if the statement were taken to mean that no inferences can be made from statistical laws unless it be assumed that these laws are dependent upon causal laws. This has sometimes been maintained, and, if I understand him rightly, this is Russell's view. But that is not what I meant to assert. There are two reasons why it is not easy to get clear about this point. The first is the tendency to confuse two statements that are in fact quite different. These are: (1) 'The truth of this conclusion is only probable'; (2) 'The conclusion (of an inference) states that such and such an event is (more or less) probable.' (1) is a statement about *probable inferences*; (2) is a statement concerning *probable events*. The second reason is, perhaps, peculiar to Eddington's expositions and

is due to his unfortunate usage of the word "inferences". I will consider these difficulties in turn.

We have already seen that no statement of a scientific law can be known to be certainly a true statement; we have noticed that this discovery is in no way connected with the discovery of Heisenberg's Principle. This principle relates to probable events. But the phrase "probable events" is itself a queer one, and is likely to lead to still further confusions. The statement 'The event X is probable' must not be taken to mean 'That the event X will happen is probably true', for this would be to fall into the confusion we are trying to avoid. There are not *two* classes of events, *probable events* and *non-probable events*, as there are *two* classes of men, *white men* and *non-white men*.[1] There are just *events*, and there are probabilities whether there will be an event of such and such a character, or not. Thus 'The event X is probable' must be taken to mean, 'An event X may happen but it may not happen, and there is no event the happening of which is decisive with regard to its happening.' I think this must be what Eddington means when he says: 'In the present scheme of physics every phenomenon has a certain degree of indeterminacy.'[2] Such an interpretation slides easily into the notion of caprice. Clearly the notion of caprice underlies the expression, at one time in common use, that an electron 'chooses' to make one jump and not another. It is also clearly involved in the account given by Jeans of the Principle of Uncertainty.[3] Moreover, the phrase "a capricious event" is very easily substituted for "an event which cannot be accurately ascertained". Although it is true that a capricious event could not be accurately ascertained (for

[1] To suppose otherwise is to fall into a syntactical confusion.

[2] *Symposium*, p. 174.

[3] See *M.U.*, pp. 25 *seq.*

whether it would happen or not could in no way be ascertained at all), the converse does not hold. Indeed, the notion of *caprice* is not applicable outside the domain of human actions. But if, for a moment, we allow "a capricious event" to mean "an event in no knowable relation to any other event", then it is clear that such an event could not come within the sphere of scientific knowledge. 'The present scheme of physics' can no more admit capricious events than could the Laplacean scheme. This conclusion has importance, I think, with regard to the bearing of Indeterminacy upon free will.

The second difficulty referred to above relates to Eddington's usage of the word "inferences". On more than one occasion he has insisted that 'the universe is populated with inferences'. He stresses the point that familiar objects 'are just as much inferential as a remote star inferred from an image on a photographic plate or an "undiscovered" planet inferred from irregularities in the motion of Uranus' (*N.P.Sc.* 92). These inferences differ only in degree, not in kind. He proceeds,

> The shadow of the moon on Cornwall in 1999 is already in the world of inference. It will not change its status when the year 1999 arrives and we observe the eclipse; we shall merely substitute one method of inferring the shadow for another. The shadow will always be an inference. By the shadow I here mean the entity or condition in the physical world, viz. a comparatively quiescent state of the aether, not the sensory perception of darkness in a number of human and animal minds.

Three criticisms may be made with regard to these statements. (*a*) Since the shadow is a physical entity, viz. a certain combination of the sun, the moon, and the earth, and since these three bodies are not always in that combination and will not be until 1999, it is certainly not true

to say that the physical world does *now* contain that combination—the standing of the sun, the moon, and the earth in certain mutual relations. But in 1999 that combination will be in the physical world (unless astronomers have made a mistake). Accordingly, it is difficult to know *what* meaning to attach to the statement that 'It will not change its status when the year 1999 arrives,' since 'It' must refer to 'the shadow of the moon on Cornwall'. I venture to suggest that Eddington attaches a meaning to this statement only because he regards 'It'—i.e. the combination—as an inference.[1] Now the inference *that in 1999 the shadow of the moon will be on Cornwall* is the conclusion of certain modes of thinking entertained by scientists. We *believe* now (as a result of inferring *conclusions* based upon the fact that men have had certain sensory perceptions) that the conclusion concerning the combination is true. This conclusion is a statement about what will happen; we believe now that this statement is true (or has a high degree of probability of being true). In 1999 this belief, *now* entertained, will be shown either to have been true or to have been a mistake. But there is no sense in which it can be said that what the statement is about, viz. the shadow of the moon on Cornwall, is 'already in the physical world', for to say this is to say that the sun, the moon, and the earth are *now* standing in certain mutual relations; it is, however, clear that they are not *now* standing in *these* mutual relations.

(*b*) Eddington is making similar confusions due to his extraordinarily loose use of the word "inference", when he says that 'The external world of physics is a universe

[1] This is shown very clearly in the original form in which Eddington stated this point, in the *Symposium* paper: 'It is not easy to see in what way it will gain in status'.

populated with *inferences*.' The upshot of this mystification is surely that every physical entity which is known to us at all is known to us only under the description of being a factor in a set of certain causes of effects which are not physical, namely, human sensory perceptions.

(*c*) The point of Eddington's mystification here, as well as his insistence that these 'inferences' differ only in degree, is to reinforce the argument that 'every physical phenomenon has a certain degree of indeterminacy'. But I suggest that the argument suffers from the confusion I have already discussed between a probable conclusion and a probable event. This confusion appears very clearly in a statement made by Eddington in close connexion with his mystifying remarks about the eclipse. He sums up his argument to establish that 'the indeterminism of the future applies to all phenomena, although for some it may be practically insignificant', with the remark: 'It is impossible to trap modern physics into predicting anything with perfect determinism because it deals with probabilities from the outset' (*N.P.Sc.* 105). Surely 'with perfect determinism' in this sentence just means 'with perfect certainty'? If so, then the upshot of the argument is that nothing can be *known* to be certainly true although it is *reasonable* to believe that many inferred conclusions are true.

(2) I come at last to the second question raised on page 191 above. The question relates to the connexion between determinism and prediction, and to the connexion between prediction and rationality. In view of the preceding discussion this question can be dealt with briefly. It is clear that predictions can be made (i.e. inferences concerning what will happen) on the basis of statistical laws. Such predictions can never be *known* to be certainly true. But no predictions concerning the physical world can be *known*

to be certainly true, since we have no logical ground for assuming that our extrapolations are correct. This is popularly expressed by saying, 'We cannot *know* that the future will resemble the past.' Now Heisenberg's Principle has shown us that there is a finite limit to the possibility of constructing functions that can be used for extrapolation. Consequently, there is a finite limit to the possibility of predicting with accuracy. But 'probability functions' can be constructed which permit us to infer subsequent states within precisely determined limits (i.e. with an inaccuracy never greater than h) and by means of exact laws. Accordingly, predetermination is not essential to the intelligibility of natural happenings. To see that a happening is intelligible is to see that there are a set of premisses from which it could be inferred. Nothing is intelligible until it *has happened*, although *the statement that it will happen* may be intelligible. A rational world is a world in which what happens is capable of being brought into an intelligible scheme. What is essential for intelligibility is that what happens should happen in accordance with discoverable laws.

(3) The glee of some, the gloom of others at the rejection of determinism is not difficult to understand. Those who mourn do so, I believe, because they are afraid that science is becoming irrational or because they have an aesthetic preference for an ideal such as that of Laplace. I think that the latter is probably the case with Einstein, who is desperately seeking to find some way of reintroducing a completely deterministic scheme of law into modern physics. But I fancy that no one wishes to reinstate the belief that 'everything happens with machine-like precision' because it is now clearly recognized that the 'machine-image' is a bad one, i.e. inappropriate to physical happenings.

Those who rejoice do so, I believe, for one or other of two reasons, frequently for both. They think that the rejection of determinism leaves room for the admission of mind into the physical universe, and removes 'some of the difficulties connected with Free Will'. 'It so far modifies the problem,' Eddington says, 'that the door is not barred and bolted for a solution less repugnant to our deepest intuitions than that which has hitherto seemed to be forced upon us' (*N.P.Sc.* 74). He finds the standard definition of determinism in a well-known stanza of *The Rubáiyát* of Omar Khayyám:

> With Earth's first Clay they did the Last Man's knead,
> And there of the last Harvest sowed the Seed:
> And the first Morning of Creation wrote
> What the Last Dawn of Reckoning shall read.

I am entirely in agreement with Eddington in taking the poet's statement as the standard in the attempt to decide the bearing of the rejection of physical determinism upon the problem concerning human freedom. It is perhaps doubtful whether this version of determinism can be regarded as appropriate to 'the scheme of deterministic law' as assumed by the older physicists for the purpose of their scientific work. To the extent to which it is appropriate I think that the older physicists were subject to an illusion, just as they certainly were in believing that the physical universe could be conceived on the model of a great machine.

It is to be noted that the poet is concerned to insist that what will eventually be is predetermined by what has been 'from the beginning'. Thus the universe is regarded as a closed system in which everything that happens is causally necessary. The suggestion is of an inevitable unrolling of a causal sequence in which the last elements in the sequence are in some sense 'contained' in the first elements. The

metaphor of 'unrolling' is obscure; it is the source of much confused thinking on this topic as on other topics.[1] But it must be admitted that it is by no means easy to find language that does not encourage confusion in the discussion of determinism, its connexion with predestination, and its bearing upon free will. In this discussion the disputants on both sides have 'found no end in wandering mazes lost'. Omar Khayyám's statement presents the picture of a universe in which everything is predestined, but his vision recalls the nineteenth century nightmare. All the imagery of Fitzgerald's poem suggests that human beings are puppets controlled by Fate. *The Rubáiyát* is, indeed, commonly regarded as an expression of Fatalism and pessimism. Consider for instance,

> But helpless Pieces of the Game He plays
> Upon this Chequer-Board of Nights and Days;
> Hither and thither moves, and checks, and slays,
> And one by one back in the closet lays. (LXIX.)

And again,

> Oh Thou, who didst with Pitfall and with Gin
> Beset the Road I was to wander in,
> Thou wilt not with Predestined Evil round,
> Enmesh, and then impute my Fall to Sin. (LXXX.)

From this nightmare belief Huxley, it will be remembered, sought deliverance in the substitution of 'will be' for 'must be', of 'unbroken regularity' for 'inevitable necessity'.[2] Eddington, we have seen, seeks deliverance in the

[1] Cf. Leibniz' views concerning preformation. The difficulties encountered both in thinking in terms of a closed system and in terms of a system that is not closed reappear, in a different form, in the controversy concerning preformation and epigenesis.

[2] See Chap. VII, above.

substitution of 'predicting what *probably* will happen' for 'predicting what *certainly* will happen'. Both these deliverances seem to me to be extraordinarily futile. I have already dealt with Huxley's effort to escape and do not wish to add anything more to my discussion of his confusions. Eddington has made a much more strenuous effort to show that there is nothing to be worried about.

But how are we human beings to escape from puppetdom simply by discovering that 'they' do not 'write down' what we *certainly* shall do but only what we *most probably* will do? It may be objected that Eddington does not hold that there is any 'they' (or He) to predict what we shall do (either certainly or probably). But I think that that objection can hardly be maintained in defence of Eddington's argument. For Eddington has, it seems, accepted the view that the deterministic scheme of law involved in classical physics created difficulties in the way of asserting human freedom of action and that modern physics by destroying this deterministic scheme has, to some extent at least, removed these difficulties. Accordingly, I think that Eddington's revision of the 'old determinism' only entitles him to rewrite Omar Khayyám's lines:

> And the first Morning of Creation wrote
> What at the Last Dawn of Reckoning would be the relative distribution of frequencies and what would most probably be the position of each electron.

That, it seems to me, would spoil the poetry without redeeming the situation. The problem that confronts Eddington is to get as much uncertainty, or 'indeterminacy', as he can out of the miserably small amount represented by Planck's constant. He is himself profoundly convinced that a living body is just as much a macrophysical system as a dead whale is. That being so, once it has been admitted

that human actions would be completely unfree if the ideal of Laplace were possible of attainment, it cannot be maintained that all that is required for human freedom is some amount of uncertainty in the domain of microphysics.

The conditions of the problem are squarely faced in all Eddington's numerous discussions on this topic. There might seem to be three possible alternatives: (*a*) human actions are determined in precisely the same way as physical events are determined, and these are predetermined; (*b*) physical events are not predetermined, so that it follows that human actions are not predetermined; (*c*) *all* events are predetermined, but human *actions* are not *events*, so that the notion of determination does not apply to human actions. Eddington rejects, in my view rightly, the third alternative. This alternative clearly has the no doubt welcome consequence that no conclusions drawn from physics are relevant to the discussion of human freedom. But it is faced with an insuperable difficulty. For, 'man has a body as well as a mind'.[1] It is useless to allow a man to think what he likes whilst 'he can only say that which the laws of physics preordain'. But this is all the freedom that the third alternative allows. Accordingly, Eddington accepts the second alternative. The difficulty that confronts those who accept this alternative is, as we have seen, the ridiculously small amount of indeterminacy[2] that the

[1] See *N.P.Sc.* 86. The statement continues: 'The movements of his limbs, the sound waves which issue from his lips, the twinkle in his eye, are all phenomena of the physical world, and unless expressly excluded would be predetermined along with other phenomena.' Cf. *N.Ph.W.* 312 and see also p. 242 below.

[2] Eddington seems to use 'indeterminacy' and 'freedom', in this connexion, as synonyms. I shall, however, later find it convenient to distinguish the use of these two words, and shall accordingly use the former except when quoting from Eddington.

measure of the uncertainty relations involves. 'If our new-found freedom,' says Eddington, 'is like that of the mass of ·001 mgm. which is only allowed to stray $\frac{1}{5000}$ mm. in a thousand years, it is not much to boast of. The physical results do not spontaneously suggest any higher degree of freedom than this' (*N.P.Sc.* 88). There is an appreciable degree of indeterminacy only in the case of electrons and atoms; human beings are polyatomic; human actions take place in the world of macroscopic bodies. 'Although the door of human freedom is opened,' says Eddington, 'it is not flung wide open; only a chink of daylight appears.' How is the door to be prised open wide enough to let in the full daylight?

Eddington's attempt to solve this problem depends upon his general view that 'the physical world of atoms is the abstract symbolic representation of something' (*N.P.Sc.* 88). In the case of inorganic phenomena we know nothing about the background; in the case of mental phenomena we do. But there is a point of contact of the physical world with consciousness; this point of contact is the self or mind, 'whose physical aspect and symbol is the brain cell'. Now the Self acts as a unit; it is expressed in 'unitary behaviour'. Consequently, he urges, 'we must attribute some kind of unitary behaviour to the physical terminal of consciousness, otherwise the physical symbolism is not an appropriate representation of the mental unit which is being symbolized'.[1] This statement is open to the gravest criticism. But let that pass for a moment. Eddington sees clearly enough that it is not sufficient that the self should be able to decide the behaviour of atoms individually. As he had previously put the problem: 'we must attribute to the mind power not only to decide

[1] *N.P.Sc.* 89. Cf. *N.Ph.W.* 312.

the behaviour of atoms individually but to affect systematically large groups—in fact to tamper with the odds on atomic behaviour' (*N.Ph.W.* 313). Thus we are finally faced with the admission that there is an immense cleavage between the behaviour of inorganic bodies and the behaviour of a human being. This cleavage may not do 'violence to physics' but it seems to me to leave the problem of free will just where it was before physicists became indeterminists.

The serious criticism to which Eddington's attempted solution of the problem lies open is that it depends upon the assumption that a set of atoms is a *symbol* of the unitary ego. Eddington takes it for granted that the ego must be symbolized by something, that physical entities, e.g. atoms, are *symbols*, and that we know by direct insight that the ego cannot be represented by a random collection of atoms. The difficulty is to see how a non-random collection of atoms can be a symbol of anything at all. Further criticism of Eddington's attempt to solve his problem would merely repeat the criticisms, made in Chapter IV, of his conception of the mind and its relation to the physical world on the one hand and to the world of physics on the other.

I cannot help thinking that Eddington is on the wrong tack in trying to rest any part of the case for the freedom of man upon the present acceptance of indeterminism in physics. He himself stresses 'two aspects of human freedom', namely, responsibility and self-understanding. With regard to the first he says that he has nothing to add to the attempts that have been made to show *how* we can 'be responsible for our own good or evil nature'. But, in his view, the point of central importance is that we do seek *truth*; it is 'I who ask the question.' Any theory of Nature must be consistent with the fact that human beings do mind

about truth. He says, concerning a piece of mathematical research,

> The assurance that I most desire is that the result which I write down at the end shall be the work of the mind which respects truth and logic, not the work of a hand which respects Maxwell's equations and the conservation of energy. (*N.P.Sc.* 90.)

This argument may perhaps be stated as follows : If previous physical events completely determine all the movements of my body, then the movements of my pen are also completely determined by previous physical events. But the movements of my pen express the results of those mental processes that we call reasoning and seeking for truth. But if the movements of my pen are completely determined by previous physical events, how can it be held that my mental processes have anything to do with the movements made by my pen. And if my mental processes have nothing to do with the movements of my pen, how can we explain the importance attached to those movements of my pen which record what is *true* ? This argument seems to Eddington to explain reasoning away, and to make of it a process quite other than he feels it to be. I agree that there is a difficulty ; it is the difficulty of the gap between conscious processes and physical events. But surely Eddington's merely negative contention that such bodily processes are not *completely* predetermined by previous physical events does not remove the difficulty. This may be necessary ; it is certainly not sufficient. I do not think that it can reasonably be maintained that physical indeterminism is capable of affording any help in this problem.

Our conviction that we are responsible, our desire to know what is true and reject what is false, constitute part of the *data* that must be taken into account in any attempt to consider the relation of human beings to their physical

environment; they are not to be deduced as the result of a certain development in physics. Either it must be shown that responsibility is an illusion, or it must be shown how physics can be reconciled with the fact of responsibility, or it must be shown that no reconciliation is required because there is no conflict. It is clear that Eddington rejects the last alternative and could not accept the first. He pins his faith to the second.[1] He believes that the present position in physics entitles him to say, 'I think there is no longer any need to doubt our intuition of free will. Our minds are not merely registering a predetermined sequence of thoughts and decisions. Our purposes, our volitions are genuine; and ours is the responsibility for what ensues from them.'[2]

This is an odd saying. How can the Principle of Uncertainty assure us that our purposes and volitions are *genuine*? What can be meant by saying that we need not any *longer* doubt our intuition of free will? Suppose that Einstein were successful in re-establishing strict causality as the basis of physics. Or suppose that it were conclusively shown that Eddington's attempt to establish a fundamental distinction between the behaviour of inorganic matter and the behaviour of a living brain was untenable. Would either of these *physical* conclusions lead Eddington to doubt his intuition of free will? Assuredly not. How, then, can the results of the work of the physicists have any bearing upon this intuition?

It is interesting that Planck, the champion of strict physical

[1] Cf.: 'I attach importance to the physical unpredictability of my pen, because it leaves it free to respond to the thought evolved in my brain which may or may not have been predetermined by the mental characteristics of my nature' (*N.P.Sc.* 90).

[2] *Science and Religion*, p. 126.

determinism, is as certain as Eddington that our wills are free, and is as eager to maintain that 'spiritual happenings are determined' as that physical happenings are. And moreover, like Eddington, his certainty that we are free springs from an intuition. 'Our own consciousness,' he says, 'tells us that our wills are free. And the information which that consciousness directly gives us is the last and highest exercise of our powers of understanding'.[1] But he is not content to base human freedom upon an intuition. He strives to show that the dignity of man requires both that he should be free and that his spiritual activity should be determined. This seems to involve a contradiction. Planck argues, however, that this is not so. The alternatives are: either our actions are swayed by chance or our actions are causally determined. The first alternative must be rejected, for it is derogatory to the human personality and also inconsistent with the amount of order and regularity that each of us can detect in the behaviour of other people.[2] Accordingly, the second alternative must be accepted. In accordance with his Laplacean ideal Planck maintains that a Supreme Intelligence could foresee and predict 'every single act of the will, with all its motives' of any human being, just as the Supreme Intelligence can predict everything that happens in the physical universe. He recognizes that this

[1] *Where is Science Going?*, p. 101.

[2] Cf.: 'The dependence of each event upon preceding fact and preparatory factors gradually begins to appear under the strong light of scientific investigation, so much so as to warrant the statement that present-day scientific procedure in psychology is founded practically exclusively on the principle of causal inter-relations and the assumption of an active law of causality which admits of no exceptions. This means that the postulate of complete determinism is accepted as a necessary condition for the progress of psychological research.' (*Ibid.*, p. 155.)

contention is incapable of being proved ; it is a metaphysical statement upon which any theory of human nature as well as any theory of the behaviour of inorganic bodies must be based.

In one respect only does Planck admit that the Principle of Indeterminacy has any bearing upon the question of free will. Its bearing is that it enables us to understand how it is that an individual subject cannot himself forecast his *own* actions. Information about oneself supplies a motive to one's own future actions ; hence, I am not accessible to myself in this respect. Heisenberg's Principle has shown us that ' no method by whose application the object is essentially altered can be suitable for the study of this object '.[1] Thus the individual does not feel himself to be the object of predictions, hence he can be conscious of freedom. Planck is content to sum up the relation between causality and freedom in a truly Kantian manner : ' The law of causation is the guiding rule of science ; but the Categorical Imperative—that is to say, the dictate of duty—is the guiding rule of life.' [2]

Planck is anxious to refute indeterminacy in physics in order to save the dignity of man. Eddington is anxious to increase the amount of indeterminacy, recently introduced into physics, in order to safeguard our feeling of responsibility. Sir Herbert Samuel is afraid lest the denial of determinism should make man the sport of chance and lead to irresponsibility in action and increase of unreason in politics and life.[3] Each of these three thinkers has reacted

[1] *The Philosophy of Physics*, p. 74.

[2] *Where is Science Going ?*, p. 167. Cf. : ' The fact is that the principle of causality on one hand and free will on the other refer to totally different matters.'—*The Philosophy of Physics*, p. 73.

[3] See list of Articles by Sir H. Samuel, cited in bibliography.

to the contemporary situation in physics in conformity with his own philosophy of life. That this is so is not in the least to be wondered at. Scientific theories may in part guide but cannot decide our philosophies. What is surprising, however, is that such diametrically opposed views as those of Planck and Eddington should be professedly derived from the development of physical theories, or that Eddington and Sir Herbert Samuel should each wish to defend human responsibility by denying what the other asserts and asserting what the other denies. The explanation of this curious position is to be found not so much in divergent interpretations of the amount of indeterminacy in physical phenomena as in divergent conceptions of the nature of human freedom and the conditions of moral responsibility. They give different answers to an important question posed, but not answered, by Eddington:

> Is the human will really more free if its decisions are swayed by new factors born from moment to moment than if they are the outcome solely of heredity, training and other predetermining causes?[1]

The discussion concerning the answer that should be given to this question belongs to the next chapter.

[1] *The Mathematical Gazette*, May 1932, p. 79.

Chapter X

HUMAN FREEDOM AND RESPONSIBILITY

'Si necessitatis est, peccatum non est; si voluntatis, vitari potest.'
PELAGIUS

'For every tree is known by his own fruit. For of thorns men do not gather figs, nor of a bramble bush gather they grapes.'
The Gospel according to Saint Luke.

WHAT do we suppose ourselves to be asserting when we say that we are free, or, alternatively, that our actions are free, or, at least, that sometimes we act freely? I think that the attempt to answer this question is the right way to approach the problem of human freedom. Unless this question be clearly answered, we cannot hope to understand whether there is any ground for supposing that classical physics or evolutionary biology involves the denial of freedom; whether recent physical speculations lead to the reaffirmation of freedom; or, finally, whether these speculations have no bearing at all upon the problem.

The common reader will have noticed that it is usual to speak of the *problem* of free will. Why is there a *problem*? To be confronted with a problem is to be aware of a difficulty. In this case the difficulty is a difficulty presented to the intellect, to be solved (if at all) by thinking; it is not to be solved by insisting upon an *intuition* of free will, nor by deploring the consequences if it should happen that we are

not free. But wherein exactly does the difficulty lie? It is futile to seek to resolve a problem unless we know what exactly the problem is. Yet, oddly enough, it is by no means easy to track this problem down. I am not unaware of the danger of having missed the problem altogether.

Men laugh; they fall in love, make friends, fight, compose symphonies, rejoice in studying the ways of electrons or the behaviour of birds or of men, or seek to advance the science of geology by examining the distribution of sea-urchins in the crust of the earth. Certainly questions may be asked about any one of these activities—questions of genesis, of biological function, of sociological significance. It takes a biological psychologist to explain that falling in love is a Shavian experience; it takes a sober philosopher so to analyse laughter as unwittingly to occasion that experience. The common reader continues to laugh and to fall in love. He is ready to insist that the world contains not only moving bodies but also thinkers, artists, and lovers. These provide data of which the various special sciences must take note; the scientists must not construct elaborate theories which leave no room for these experiences of our daily life. Finding something witty we are amused. We may then consider wherein wit consists. If we are presented with an analysis of wit that makes it an inexplicable mystery how we could ever be amused by a witty joke, we reject the analysis. The analysis must fit the experience. Samuel Johnson, 'the apostle of common sense', exclaims, 'Sir, I know the will is free, and there's an end on 't'. Yet Eddington speaks of doubting 'our intuition of free will'. Most common readers will not fail to understand Tennyson when he speaks of

> '. . . this main miracle, that thou art thou,
> With power on thine own act and on the world.'

Shocking language, no doubt, but not *unintelligible* to those who have not been debauched with much learning. I venture to think that most of us have used not unlike language—'I have the power to keep this promise'. I do keep it. 'I have the power to alter this situation.' I do alter it. The mill stream has the power to turn the wheel. The sun has the power to melt the wax. Neither the mill stream nor the sun is (I presume) conscious of having power, since neither is a conscious being. *I* am conscious of *having power* to act, of *intending to* act, of *acting now*. Maybe there is a mystery in the fact of being conscious; perhaps we make a mystery only by trying to explain consciousness in terms of what it isn't. What it is *to act*, to be *conscious of acting*, to have a *power of acting* in such and such a way—these admit of analysis, just as the sun's power of melting the wax admits of analysis. With these analyses we are not concerned. The 'problem of free will'—which Eddington says has rent Scotland 'from the synod to the cottage'—does not present itself to plain men as a problem of analysis. Rather, it presents itself as a problem of reconciliation. The reconciliation required is between the fact of our intuition of freedom, our beliefs with regard to the correct analysis of that intuition, our beliefs concerning the nature of the conditions of moral responsibility, and our beliefs with regard to the nature of the physical world within which our actions have consequences. It is with the last two that I shall be concerned.

It is not quite easy to make clear to oneself what precisely is involved in the notion of moral responsibility. I take it for granted that it is of persons that moral responsibility is asserted. It is the notion expressed by '*I* am responsible' that calls for examination. We do often use expressions such as 'Grit in the motor was responsible for the failure

of the electric light', 'It was meeting a fierce dog in a narrow passage when he was a child that is responsible for his claustrophobia'. But the use of the word "responsible" in such expressions is, I suggest, somewhat metaphorical; it can be replaced by words expressing *nothing but* causal connexions. Either this is not the case with 'moral responsibility' or the word 'moral' adds nothing. There would be, then, no problem.

At the outset it is important to insist upon the distinction between 'I am responsible *for* something' and 'I am responsible *to* someone'. The latter presupposes the former but not conversely. I may have responsibility *for* although there is nothing *to* which I am responsible; in that case "I am responsible to" has no sense. Probably no one would dispute that *responsibility for* is more fundamental than *responsibility to*. But it seems to me that in the prolonged controversy concerning free will the main interest has been in the attempt to justify our *responsibility to*, or to deny it, rather than to consider the logically independent question concerning the meaning of "responsible for". It is the latter that is important; it is the former that has been prominent in the controversy concerning free will.

Ordinarily, I think, we accept responsibility for those changes in a situation which result from our activity. For instance, at the moment I am responsible for writing these words. These black marks are now appearing on this paper because I have decided to make them and am carrying my decision into effect. The language just used is the ordinary cause-language of everyday life. Continuing to use this language, the point may be put as follows: 'I am responsible for this' means 'This has happened [or is happening now] and my decision is a causal factor in its happening.' In my opinion the language I have just used is sensibly used, i.e.

it makes sense and expresses an experience which everyone can recognize as familiar. We do recognize that our decisions are sometimes *effective* in bringing about a change in a situation, i.e. our decisions are part-causes of an effect. As Eddington says, albeit in a different context, 'the denial of determinism, or as it is often called "the law of causality", does not mean that it is denied that effects may proceed from causes. The common regular association of cause and effect is a matter of experience.'[1] It is again a matter of common experience that we distinguish between 'doing something accidentally' and 'doing it deliberately'. If, when walking along a pavement, I step on a banana skin, stumble, knock against a passer-by and throw him over into the road, then I am not responsible for the *accident*. I did it inadvertently.[2] No doubt there are degrees of inadvertence, but with these we need not be concerned. It is enough if the distinction be granted. I do not dispute that we ought to remedy, as far as is possible, and if possible at all, the damage done inadvertently. I am here concerned, however, only to maintain that what we inadvertently do is just that for which we are not conscious of responsibility.

I have already suggested that when we speak of responsibility in the ethical sense we are not using mere synonyms for causation. The additional notion that is present is that of *value*. To admit responsibility is to admit both that something is brought about (i.e. is caused) and also that what is brought about is good, or is evil. In other words, the notion

[1] See *N.P.Sc.* 74. Eddington regards 'the law of causality' as a *generalization* from our experience that effects follow from causes.

[2] Since I am not here primarily concerned with ethical questions, nor to assess responsibility but only to fix the subject of it, I do not enter into a discussion concerning the need for carefulness in, say, walking in a crowded street.

of responsibility involves the recognition of value although not necessarily an explicit judgement *that* something is valuable. The proud child who, pointing to the card-castle he has built or to the paper he has cut up, proclaims 'I did it *myself*', is claiming responsibility for something good achieved. The point I wish to stress is that we are all quite familiar with experiences of this sort. This is a dogmatic statement. The reader can test its truth so far as his own experience is concerned. To me it does not seem that any puzzling questions arise in connexion with the statement—'*I* did it', or with its elaboration in the form 'I am *responsible for* it'. To accept responsibility is to deny compulsion; it is not to deny causation, for not all causation is a form of being compelled.

The *problem* of free will does not arise until we pass from the notion of being responsible *for* to the notion of being responsible *to*. The sentence 'I am responsible to . . .' requires completion. It can be completed by any one of three variants, namely, (1) God, (2) my fellow-members of society, (3) myself. What justifies the use of the same word, 'responsible', in each of these three contexts is that in each case there is involved the notion of bringing something good, or evil, about. Nevertheless the use of the same word is misleading, for 'responsible to' means the same as 'accountable to', and I cannot be accountable to God in the same way in which I am accountable to the members of my society, nor in the way in which I am accountable to myself. Indeed, in my opinion, the third variant, yielding 'I am accountable to myself', is an extremely misleading, if not a positively erroneous, expression. Accountability to oneself is, in the case of evil that is done, the basis of remorse. I do not think that anyone ever does *use* the expression 'I am accountable to myself for the evil I have done', but if anyone were

to use it, then I think he would be expressing the fact that remorse is appropriate to the situation. I shall here simply assume—what I am firmly convinced is the case—that human beings do occasionally experience remorse, that it is well that they should do so, and that no troublesome puzzles arise in connexion with this experience.[1] For the purpose of this discussion it is not necessary to attempt to justify this assumption since it is not in connexion with it that the troubles about free will have arisen.

I believe that the bitterness, the intensity and the futility of the prolonged controversy concerning human freedom are due to the combination of three beliefs: (1) God created me; (2) I am accountable to God for the evil that I do; (3) God punishes me for the evil that I do. It is the fact that men sin that has made free will so burning a question; it is the belief that sin leads to damnation that has made many so eager to establish free will. The nature of the problem is well brought out in a remarkable passage from *The Confessions of Saint Augustine*:

> But I also as yet, although I held and was firmly persuaded, that Thou our Lord the true God, who madst not only our Souls, but our bodies, and not only our souls and bodies, but all beings, and all things, wert undefilable and unalterable, and in no degree mutable; yet understood I not, clearly and without difficulty, the cause of evil. . . .
>
> And I strained to perceive what I now heard, that free-will was the cause of our doing ill, and Thy just judgement, of our suffering ill. But I was not able clearly to discern it. So then endeavouring to

[1] This may be disputed, but only, I think, by those who wish quite to discard values out of the world. Of course, to find a puzzle would then be self-contradictory. It seems to me that if I experience remorse for the evil I have done I am thereby recognizing that something good is attainable although I have not attained it, and may not now be capable of attaining it.

draw my soul's vision out of that deep pit, I was again plunged therein, and endeavouring often, I was plunged back as often. But this raised me a little into Thy light, that I knew as well that I had a will, as that I lived : when then I did will or nill anything, I was most sure, that no other than myself did will and nill : and I all but saw that there was the cause of my sin. But what I did against my will, I saw that I suffered rather than did, and I judged not to be my fault, but my punishment ; whereby however, holding Thee to be just, I speedily confessed myself to be not unjustly punished. But again I said, Who made me ? Did not my God, who is not only good but goodness itself ? Whence then came I to will evil and nill good, so that I am thus justly punished ? Who set this in me, and ingrafted into me this plant of bitterness, seeing that I was wholly formed by my most sweet God ? If the devil were the author, whence is that same devil ? And if he also by his own perverse will, of a good angel became a devil, whence, again, came in him that evil will, whereby he became a devil, seeing that the whole nature of angels was made by that most good Creator ? (Bk. VII, 4, 5.)

This passage relates to a period in St. Augustine's life before his ' conversion ' and only shortly after he had succeeded in rejecting the Manichaean heresy. Subsequently he solved his difficulties for himself by maintaining that owing to Adam's fall, mankind is guilty of sin, ruined, and incapable of good, but that the grace of God brings salvation. God has predestined certain men to be saved by his grace, others to be damned. That the elect will be saved God foreknows, but, if I understand him rightly, St. Augustine held that God's foreknowledge that the damned will remain in their sins does not render their sinning necessary.[1] Certainly St. Augustine held very firmly that ' the first Morning of

[1] Dean Inge, commenting on St. Augustine's view that ' in the knowledge of God " futura iam facta sunt " ', says, ' I do not think that determinism necessarily follows from these words of Augustine. God may foreknow the future as that which is going to happen, not as that which could not have been otherwise ' (*God and the Astronomers*, p. 97 *n.*).

Creation wrote what the last Dawn of Reckoning shall read'. He says, 'Just as in every seed there were invisibly and at once all that were afterwards to grow into a tree, so we are to consider that the world, as soon as God created all things, had in itself at once all things which were made in and with it. When the day was created, the later products of creation were already there, *potentialiter atque causaliter*'.[1] This view combined with the doctrines of original sin and of eternal damnation reduces men not only to puppets but to damned puppets. On this view the behaviour of the puppets is God's responsibility. He is responsible *for* their behaviour, and is not *accountable* only because there is none to call him to account. The pessimistic sense of futility engendered by such a belief pervades Fitzgerald's version of *The Rubáiyát* of Omar Khayyám.

Whether we use the name 'Fate' or 'God', there is no answer to St. Augustine's question: 'Who set this in me, and ingrafted into me this plant of bitterness, seeing that I was wholly formed by my most sweet God?' There is no answer because the assumptions upon which the question is based are mutually incompatible. The cause of a cause is the cause of that cause's effects. Hence, that which is wholly good cannot be the whole cause of that which is evil. But, according to St. Augustine, God, 'who is not only good but goodness itself', made me. Further (as St. Augustine came to hold later), he predestined me (unless I happen to be one of the elect) to reject the only means of salvation. But to be damned is to suffer evil. Hence, God cannot be both my creator and also wholly good. Thus the conclusion contradicts the premisses. There is, then, a serious muddle somewhere.[2]

[1] Quoted by Dean Inge, op. cit., p. 129.

[2] Whilst this book was passing through the press I came across a letter written by F. H. Bradley to William James about his *Will to*

A full consideration of this muddle is not required for the purpose of this discussion. It is not my intention nor is it within my competence to unravel the mysteries of the Theologians. I have dwelt upon the Augustinian doctrine of predestination for two reasons. First, because I want to insist that if God be regarded as having made me and set my ways in a predestined path, then to say 'I am responsible to God' is to say something that has no sense. We could

Believe, which seems to me to put forcibly the point I was trying to make. The letter from which the following quotations are taken is published in R. H. Perry's *The Thought and Character of William James*, Vol. II, pp. 238–9:

'I have always supposed that I am not morally responsible for mere accidents. You seem to tell me that these are all I am responsible for. But you offer me no sort of explanation. I do not understand this at all. . . . All that the ordinary man asks, so far as I can see, is that his act should come from himself and not be extraneous. I think this demand is fully satisfied by the view that the self, once in being, is an internal principle and agency—not the same with selfless conditions, nor the same even with what it is conscious of. But what has all this to do with *chance*? I cannot see.

'The trouble, I believe, has been mainly caused by the moral (or immoral) Creator. Once tell a man that another fellow, however big, has made him to be and do what he is and does, and of course he throws it on the other fellow; and his poor morality goes to the devil, or may do so. I don't understand a word of what you say about "possibilities" in connexion with this other fellow, unless you mean to say that he's not a "Creator" at all, but somehow a limited struggling sort of chap like ourselves only bigger and better, and loves us and tries to help us, and we ought to stick to him. *That's* a moral doctrine if you like, and you may even say, too, he tried to make us to be like him as well as he could and he knew how—and that's moral or not *un*-moral again. But go further and I don't think you'll save either the morality of the personal God or ours either, so far as we take him seriously and look on ourselves as his pottery. . . .' (The whole of this correspondence between Bradley and James is of interest in connexion with the topic of this chapter.)

not by invoking the Principle of Uncertainty avoid ascribing wickedness to God, nor justify our responsibility to Him since there would be no sense in which we could be said to be responsible to God. Secondly, the doctrine of predestination along with the set of beliefs out of which it developed has deeply infected the thought of Western thinkers. Its Eastern form is the doctrine of Karma with its logical consequence—belief in pre-existence. The conception of human beings as created *objects*, as manufactured articles, pervades the language used by those who are troubled about man's responsibility and God's. God is the Master Potter, men the pots—' What ! did the Hand then of the Potter shake ? ' If, tiring of this image, we echo the ' Súfi pipkin—waxing hot ', and exclaim

> ' " All this of Pot and Potter—Tell me then,
> Who is the Potter, pray, and who the Pot ?," '

we, in this machine age, slip easily to the machine-image : God is the great designer and maker of a vast machine ; men are the cogs in the machine. It is unpleasant to feel oneself a cog ; one might prefer to be a pot. Jeans, however, offers us the hope that, owing to Heisenberg's Principle, ' it is almost as though the joints of the universe had somehow worked loose, as though its mechanism had developed a certain amount of " play ", such as we find in a well-worn engine ' (*M.U.* 27). He warns us not to be misled by the analogy into supposing that this ' loose-jointedness ' is a mark of imperfection. On the contrary, it is a sign that not everything is destined to happen *exactly* as it does happen. The universe is not a piece of ' perfectly-fitting machinery ' and its amount of play is measured by Planck's constant. Sir William Bragg (writing in 1935) urges us not to let ourselves be ' oppressed by unnecessary

fears that we are but helpless cogs in a machine',[1] but his ground for hope does not seem to lie in a recognition of the inappropriateness of the machine-image but in the fact that we 'are unable, at present, to interpret in full what we observe'.[2]

St. Augustine's problem—how to fix responsibility—reappears in a curiously old-fashioned discussion of the problem of free will in Mr. John Wisdom's recent book *Problems of Mind and Matter*. His problem is to reconcile our judgements of blame with the two-fold requirement that 'blame entails free will' and that the law of universal causation must be accepted at least in the modified form that every event except the first event in the World's history is determined. 'What blame requires', he says, 'is that, however far back we go in setting out the causes of your act, we shall never come to a time at which a set of purely external circumstances, i.e. not involving you and your will, formed a complete cause of your act' (p. 118). Accordingly, if you are rightly to be blamed, the causes of the causes of the causes of . . . the causes of your decisions, however far

[1] 'The Progress of Physical Science' in *Scientific Progress*, p. 77.

[2] It is in the 'clash' of physical theories that Sir William Bragg finds hope. The following passage is remarkable, seeing that it was written in 1935:

'It is true that Nature's operations move with machine-like precision, and that all her processes, whenever we are able to repeat them, follow the rules of the experimental laboratory. But it is also true that we have another laboratory, wherever we meet our fellow-men and that there also we learn by experience, and make observations on which we base thoughts and actions. We feel that we have some control over that we do, and may act selfishly or unselfishly. If the lessons of the two laboratories seem to contradict each other, the clash is not even so definite as that in which in the physics world may set the wave theory and the particle theory in apparent contradiction, if we confuse the uses to which the two theories may be put.'

back they may be pushed in time, must include determinations of your will by your will. Hence, either 'the series of determinations of the will by the will is endless' or, if there is a first event, the series ends with this first event. Thus, on this view, my Self must have existed as long as anything has existed. I suppose that the argument is that my birth last century did not involve any break in the series of 'pre-existences' which is *my* Self, and that an equivalent to an original 'Adam' is literally a constituent of myself.

I shall not waste much time discussing Mr. Wisdom's proposal to solve the problem he has set himself. I agree with him that pre-existence is not unthinkable; it is merely not familiar to the common readers of the Western world, and is none the worse for that. What I find unsatisfactory about his discussion is due mainly to his mode of stating the problem. His language suggests an opposition between *you* and *your will* that is deservedly out of date and has prevented Mr. Wisdom from making at all clear what he does in fact mean by 'free will'. Further, I agree with Miss Helen Smith that the postulaton of pre-existence entirely fails to solve Mr. Wisdom's problem, since it is necessary that I should *know* that I pre-existed.[1] Mr. Wisdom would admit, I presume, that I do not know this.[2] It has been left to a Cambridge analytic philosopher to rediscover this fact (if it be a fact). Yet Mr. Wisdom's argument is concerned with the 'ordinary' sense in which it is held that 'blame

[1] See 'Pre-existence and Free will', *Analysis*, Vol. 3, No. 3 (Jan. 1936), pp. 40–3.

[2] I think that Mr. Wisdom's failure to notice that, unless I *know* that my acts of will form an endless series—or at least a time-long series—I cannot (on his view) be rightly blamed, is obscured from him because he looks at the problem from the point of view of an *observer*, not an *agent*. The analysis is in terms of the second person, not the first—a very odd habit of his.

entails free will'. Consequently, as Miss Smith says, 'if judgements of blame imply pre-existence, it [his argument] goes to show not that we have pre-existed, but that we are never justified in attributing blame'. This, however, is not the conclusion Mr. Wisdom wishes to enforce. Moreover, on Mr. Wisdom's view, only my *first* act of will is undetermined, and consequently, I could not do other than I am doing *now*, nor other than I shall do to-morrow, if I live so long. Presumably, according to Mr. Wisdom, I shall live so long, since he suggests no reason why my (next) death should be any more final than my (last) birth.[1] I must confess that I am very much surprised that Mr. Wisdom should suppose himself to be analysing the conditions under which the plain man believes that blame may be rightly attributed. I do not think that it is open to him to reply that the analysis of what the plain man means is often surprising, for, although common sense may have to be surprised and even shocked, ultimately the analytic philosopher professes to satisfy it.

Another Cambridge philosopher, Professor C. D. Broad, has recently discussed the question of Indeterminism.[2] He likewise has tried to find the original Adam and place him in myself. He suggests that a series of determined events may be terminated by a term which 'contains a cause-factor that is not completely determined'. Such a cause-factor he calls a causal progenitor of the series, just as Adam may be regarded as a causal progenitor of the human race. To maintain that Indeterminism is true is to maintain that there are causal progenitors in the history of the world. Professor

[1] Cf. Helen Smith: 'Either we must recognize that judgements of blame in the sense under discussion are inapplicable or we require a sense of freedom other than Mr. Wisdom's' (loc. cit.).

[2] *Determinism, Indeterminism, and Libertarianism* (C.U.P., 1934).

Broad thinks that it is not impossible that there should be such causal progenitors. But he does not think that this is all that is required in order that we should be able to say that a person *ought* to have done something other than he did, in the categorical sense of " ought " involved in the strict notion of moral responsibility. It is not enough that my actions should not be completely determined in the sense that there is a causal progenitor of my act. It is further necessary, he thinks, that my actions should be 'determined *by the agent or self*, considered as a substance or continuant, and not by a total cause which contains as factors *events in* and *dispositions of* the agent '.[1] Prof. Broad argues that those who wish to maintain that my actions are not completely determined, must take this position in order to avoid making those actions for which I am responsible mere accidents. This view—which he describes as Libertarianism —is regarded by Broad as quite indefensible. I agree with him. He thinks that it is only if Libertarianism is true that we can attach the significance which commonly is attached to ' you ought not to have acted as you did '. For, to say this requires, he thinks, that there is a genuinely categorical sense in which you *could* have acted otherwise. By ' a genuinely categorical sense ' is meant a sense of ' you could have ' which is not merely equivalent to ' you could have, if you had so chosen '. Accordingly, Broad concludes that it is ' highly probable that the notion of categorical obligability is a delusive notion, which neither has nor can have any application '.

Professor L. J. Russell has recently urged [2] that Broad is correct in maintaining that the ' strictly moral use of " ought " implies that I could have acted otherwise than I did in a

[1] Op. cit., p. 43.

[2] ' Ought implies Can ' : *Proc. Aristotelian Society*, 1935–6, pp. 151–86.

categorical sense of "could have", not resolvable into "could have if I had so chosen"'. He tries to provide an alternative theory to Libertarianism, which will ensure that an individual's actions are not completely indetermined but are indeterminate within certain limits. I have not been able to understand very well the alternative that Professor Russell offers and I do not propose to discuss it here. It is enough to say that the theory depends upon making a sharp distinction between *actions* and *events*—a distinction already emphasized by Mr. E. F. Carritt[1] and by Mr. H. W. B. Joseph.[2] There is much to be said in favour of this distinction, but I think that any theory of human freedom based upon it is still confronted with the difficulty that we act *in* the physical world and that our actions have physical consequences.[3] This is a consideration which, as we have seen, Eddington stresses. I think that it must be faced.

The alternative views that we have been considering have all been concerned with the question what the conditions are that will justify the assertion 'you were morally obliged to do so and so'. Mr. Wisdom's treatment emphasizes only the question of accountability. My impression is that Professor Broad is also concerned with this notion, but in spite of his great care in setting out the details of his argument it is not easy to see whether he would admit that 'categorical obligability' is essentially bound up with the notion of *blame*. Mr. Wisdom thinks that I cannot rightly be blamed unless my acts of will are, in the last resort, not completely determined by anything other than a previous act of my will. Professor Broad thinks that I cannot be said to be categorically obliged to act in a certain way unless my action is not wholly determined by previous

[1] *The Theory of Morals*, p. 131.

[2] *Some Problems of Ethics*, p. 39.

[3] See p. 214 above.

events and yet is determined by my self. Professor Russell agrees that the act must be mine. Eddington is, I think, in agreement on this point with Broad and Russell and believes that universal strict causality is incompatible with the ascription of freedom to human beings. He, as we have seen, seeks to find a way out by increasing the amount of indeterminacy in Nature that is allowed for on Heisenberg's Principle of Uncertainty. We saw in the last chapter that this attempt does not seem to be successful.

I suggest that no effort along the line of reasoning followed by Mr. Wisdom or along that followed by Eddington is necessary, nor has either of them any plausibility. A view that succeeds in finding room for responsibility only after the physicist has discovered that there is a 'negligible haziness' in the behaviour of macroscopic bodies can hardly be regarded as satisfactory. A view that transfers the 'ultimate responsibility' to the unknown (and hypothetical) first term of an unending series of events is in no better case. Responsibility, it must be emphasized, is ascribed to persons. Whatever difficulties there may be in the notion of responsibility, it may safely be asserted that their solution must presuppose a satisfactory account of what it is to be 'a person', what it is that "I", in the sentence "I acted freely" refers to. Eddington sees this clearly when he is discussing 'responsibility towards truth',[1] but he seems to me to forget it in his discussion of free will, which he takes

[1] See *N.P.Sc.* 311 : 'The strange association of soul and body—of responsibility towards truth with a particular group of carbon compounds—is a problem in which we naturally feel intense interest; but it is not an anxious interest, as though the existence of a spiritual significance of experience were hanging in the balance. That significance is rather to be regarded as a datum of the problem; and the solution must fit the data; we must not alter the data to fit an alleged solution.'

to be a quite distinct problem.[1] He insists that the awareness of responsibility is a datum that must be taken into account in any discussion of the problem. Does this not involve a discussion of what a *person* is? This is a point which, I think, is very clearly recognized by Professor Russell.

It cannot be denied that I did not spring *de novo* into the world. Let it be granted that 'heredity, training and other predetermining causes' (to requote Eddington's words) have made me what I am. Surely I am still responsible for what *I* do. Suppose, however, that my acts of choice, i.e. my decisions, are spontaneous, uncaused, in no sense springing from what I am. How then can *I* be said to be responsible for that which issues from that choice? It would, indeed, be a straining of language to say either that it was 'an act of choice' or that it was 'mine'. Whichever of these alternatives be correct, it seems to me to be quite clear that the Principle of Indeterminacy has no bearing at all upon the answer that should be given to the question: 'Am I responsible for that which I do?'

Nevertheless, I do not wish to deny that Heisenberg's discovery has some bearing upon 'the *problem* of free will'. For the problem has been created by the way in which our thinking has been pervaded by the image of the Potter and the pot or by the image of the machine and its cogs. The theological doctrine of predestination and foreknowledge and the scientific doctrine of determinism have so permeated our thinking and our language that we have come to believe that we *understand* how what happens here and now is predetermined by what happened *there* and *then*. It seems intelligible to us because we have assimilated predetermination to compulsion, natural laws to commands, causal connexions to constraining ties. For we know in

[1] *N.P.Sc.* 90.

our daily experience what it is to be compelled, to be commanded ; we rest comfortably in the thought of a tie which 'draws its consequence' after it much in the manner in which the vanquished warrior was drawn at the chariot of the Roman conqueror. *We* can compel things to go where we want them to (within limits). No one will, I suppose, deny that our experiences of pushing and pulling are the prototype of our conception of causation. No one ought to deny that these notions have been illegitimately intruded into the notion of universal causation or scientific determinism. This *ought* not to be denied for such a denial would show profound ignorance of the gradual process of eliminating from scientific concepts the anthropomorphic notions out of which they have grown. No one now thinks that one moving billiard ball compels another to move. But it is hard to free ourselves from these notions and our understanding of universal causation is clouded with the image of Almighty Fate. It is such notions as these that make us feel that we *understand* how our stirring of a flower compels the stars to move. I venture to believe that no one has ever imaginatively realized what it would be like for everything that happens to be bound together by compulsions. But under the influence of the success of the scientists we have given an intellectual assent to a scheme of deterministic law—a scheme which we understand only in so far as we concentrate attention upon this or that domain of Nature and import into the scientific terminology notions of compulsion that are extraneous to it. In this way 'the dominance of universal causation' is felt to be a nightmare. Heisenberg's principle has some part to play in revealing to us what it is we thought we were accepting.

Nowhere is the effect upon our thinking of the erroneous interpretation of causation as compulsion greater than in

the consideration of choice. Its effect is obvious in the way in which we speak of 'motives' and volitional acts. There is no sense in speaking of compulsion unless there is a compeller and a compelled. So, motives are thought to compel *me*. The duality is strangely persistent in our thinking. It is responsible for the wholly unwarrantable separation of the self from *its* acts, of the motive from the act, of the act from the choice, and of the decision from the thing done. Our everyday language is full of its implications. We speak of ourself as enslaved to our passions, and then, as constrained by our motives. We go on to ask what compels the motive. Hence there has grown up in our imaginative thinking the picture of a man as the victim of a power from which he cannot extricate himself, and we find with horror that *ourself* is that man. From that image we try to free ourself by thinking of *ourself* as compelled by nothing, not moved by motives, yet ourself acting and compelling. The absurdity of the image of *myself* as the victim is the secret of the strength of the Indeterminist's position. But it is also its weakness when offered as an account of human freedom for it springs from the illegitimate image of motives as compelling forces,—an image due to an unwarranted duality.

'A body impressed by no external forces'—in these words we find the image of a *freely* moving body. In thinking as scientists we have freed ourselves from the erroneous notions implicit in the words "forces" and "impressed". We find it harder to attain a like clarification in our thinking about human actions. A body (or a material system) is compelled, i.e. caused, to behave in such and such a way when it comes into connexion with another body (or material system). So it is with men. *I* am compelled to move when a stronger body, man or rock, comes into

violent contact with me. He *seizes* me; he *compels* me; we are both bodies in a material system. But if another man gives me *reasons* why I ought so to act and not otherwise, he does in no sense *compel* me; but my doing is *caused*. In the former case my behaviour is unfree; in the latter free.

It betrays confusion to ask: 'Is my act free?' It is persons who are free. My acts are determined in the quite precise sense that they proceed from the person I am. 'What significance', asks Eddington, 'is there in my mental struggle to-night whether I shall or shall not give up smoking, if the laws which govern the matter of the physical universe already pre-ordain for the morrow a configuration of matter consisting of pipe, tobacco, and smoke connected with my lips?' The question is badly posed. Laws do not *govern* in any proper sense of "govern". This is the compulsion-image again. Oddly it persists in the thinking of those who seek to oppose to the governance of laws the governance of *chance*. It is in this way that the ethical Indeterminist makes *me* a collection of acts each of which is governed or swayed by chance.[1] But is it not absurd to say 'chance governs'? The persistence of the problem of free will seems to me to be due to the fact that both sides to the controversy are content to use the same language. The Indeterminist says that chance governs what I shall do to-morrow. The Fatalist says that my morrow is determined no matter how I struggle. This is a sheer mistake based upon a contradiction, which makes *me* the passive object; whereas *I* am the actor. The morrow is in part determined through my struggling. It is the nominative case we need to use, not the accusative. The

[1] See James: 'The Dilemma of Determinism', in *The Will to Believe.*

duality which puts me into the accusative case is again prominent when we speak of *my* character leading *me* to act in such and such a way. But there are not two entities—I and my character; there are two different ways, appropriate for different contexts, of speaking about the one entity, namely, the *person*, i.e. *myself*.[1]

If to-morrow the pipe is between my lips then it is that configuration of matter that was predetermined; if it is not between my lips, then it is the other configuration that was predetermined. But we must be careful to include in that which predetermines the configuration all that is a factor in bringing it about. We must not isolate *my struggling* from the predetermining causes and then put the results of my struggling into the determined effects. Eddington's difficulty arises, I think, partly from the fact that he first makes a sharp distinction between I, *myself*, a spiritual agent who experiences spiritual struggles, and the material world; then he remembers that all future configurations are determined by past configurations but wants somehow to find *me* in that future configuration. Probably Eddington would not recognize that this is the form of his question. The standpoint from which Eddington discusses this question is that of the ordinary man who happens also to have a great deal of scientific knowledge. The ordinary man is an unphilosophical dualist. He is a dualist because he believes that his body is part of Nature whilst he is *himself* a spirit not wholly, if at all, controlled by bodily laws. He is unphilosophical because he does not see the need to ask how this distinction of his spiritual self from his body can be reconciled with the belief that *he* can affect alterations in the material world and be affected by such alterations. His extreme dualism is shown in his readiness to accept the view

[1] Cf. Adam Smith's 'little man within the breast'.

that the universe exhibits complete determinism and at the same time to insist that he is himself a mind, or spirit, that falls without the causal scheme. It is for this reason that the theories of the evolutionary biologists so profoundly affected him. These theories made his very self a part of 'the great series of causes and effects' of which Huxley spoke. It was the work of Huxley and his contemporaries that prepared the ordinary man for the joyful acceptance of the belief that modern physics has abolished determinism. Eddington, with a greater insight into the implications of deterministic law, has nevertheless approached the problem in the form in which it dimly presents itself to the ordinary man. It is this I think that accounts for the otherwise incomprehensible fact that Eddington looks for a solution of his problem in 'the substitution of high probability for certainty'.[1] He can see no other way out.

I suggest that the solution of his difficulty is to be found only in a reconsideration of the form in which it has been posed. True that *I* am in a material environment. But this language, though it has its uses in some contexts, is misleading. In the investigations of the physicist it is not difficult to distinguish between the environment and the object *in* the environment. Physicists do not usually speak of 'environment' and 'object in it' but of relatively isolated systems and sub-systems. How much is to be regarded as falling within any given system is decided by the problem under consideration. This is the clue we must follow. How do *I*, the person who acts, draw the distinction between *I* and my *environment*? Very differently on different occasions, depending upon my mood, my bodily health, my present success or want of it, my fears and hopes at the moment. But, however I draw it, I need to remember that

[1] See *N.P.Sc.* 303.

I am never to be set over against the material world in a way analogous to that in which one billiard ball is set over against another billiard ball moving towards it. I am an embodied mind. *My struggling to give up smoking* is itself an element in the world. Our tendency to forget this is but another evidence of the way in which we allow the physicist to dominate our thinking. We accept from him the notion of a Laplacean world ; and then we try in vain to reconcile our acceptance of this world with our belief that the worth of human persons requires that persons should be free. Laplace's Supreme Intelligence, it will be remembered, had occasion to take note only of the *heaviest* and the *lightest* atoms and of their movements and configurations ; nothing that the ordinary man values had any relevance to His problem. This abstraction of certain characteristics in the world, and the study of them as thus isolated, is legitimate and necessary for the purposes of the physical scientist. But we create a pseudo-problem when we try to fit human beings in a world thus conceived as though it were *the* world in which human persons act.

Nevertheless, there remains a difficulty—not a problem of responsibility but the sense of frustration. For the world in which we act is one in which other persons also act, and their actions conflict with mine, thwart my desires, and bring me unmerited sufferings. So also do I to them. And not persons only but material bodies and natural happenings are intractable to my wishes. It is not always so ; that it should sometimes be so is enough. Does not the sting of the problem lie just here ? It stings because sometimes I feel helpless, feel compelled, feel useless, feel that however much I may try and whatever I may do, I cannot do what I want to do although I know that what I want is worth while. But is it not a fact that sometimes I am indeed help-

less and frustrated. Certainly I am not 'a helpless cog in a machine', not because I am never *helpless* but because the machine-image wholly misdescribes what I am. No 'solution of the problem of free will' can make it false that what *I can do* is not wholly dependent upon what *I am*. My freedom of action is limited because I do not dwell alone as well as because I have incompatible desires and insufficient knowledge of the world in which I live. No failure to solve 'the problem of free will' affects the fact that I am what I have become and am becoming, and my actions are in part the outcome of what I am becoming. If everyone acted well, if life were wholly good, if I were never oppressed by the sense of frustration, should I be worried by the question, '*Could* I have acted otherwise?'

It is not without significance that the problem of free will presented itself to Mr. Wisdom in the form—'blame entails free will'. Broad's attitude, too, is mainly retrospective. In my opinion, what is most important is that we are responsible for that which we are going to bring about; afterwards we *shall have been* responsible, and can then be accountable to some one. Freedom and responsibility, it must be repeated, appertain to persons, not to choices, not to bodies, not to desires. Is there any difficulty in acknowledging that I am responsible for the evil that I do? Or for the good? I think not. Responsibility is different from causation, I repeat, only because that which proceeds from my act is evil, or is good. We value courage; we hate cruelty. It is because I recognize that courage is good that I can experience remorse for a cowardly act. It is because I hate cruelty that I condemn one who acts cruelly. St. Augustine's question: 'Yes, but Who made you?' is irrelevant. It seems to be relevant only because we are thinking in terms of *accountability to* whereas we ought to

be thinking in terms of *responsibility for.* Certainly I can be called to account by the fellow-members of my society. Punishment and reward are social matters. To the extent to which values are recognized by a society to that extent I can rightly be called to account for the evil that I do, nor is there anything to object to, should society reward me for my occasional good deeds. But I could not rightly be called to account for an evil *for which* I was in no sense responsible, i.e. to the occurrence of which I had in no way contributed. If I act cruelly I can rightly be punished by the fellow-members of my society, because and only because cruelty is evil and I could have avoided being cruel, *had I so desired.* It is in fact the case that punishment may sometimes make me desirous of avoiding evil ; it is not impossible that punishment may make me realize that what I have done is evil. The punishment is on account of evil that has been done. The justification of punishing lies in the conditions of the welfare of society. Sometimes ' it is expedient that one man should die for the people '. This is the rule of expediency. Social authorities can adopt no other standard since they cannot know *what I am* ; they can judge only of what they observe me to do. That which I can be observed to do is a partial indication of what I am and of what I am becoming. But it is a partial indication only. It is dangerous to attribute to the powers that be—to the State—an insight into my nature.

There is no less a danger in conceiving of God as at once my Creator and my Judge. This danger is implied in St. Augustine's problem. To this danger reference has already been made above. Its discussion would seem to lie beyond the scope of this book were it not for the fact that ' the new physics ' has been called in to solve the problem of free will. In his recently published Cunningham Lec-

tures, the Rev. J. H. Morrison repudiates the notion that the new physics has any bearing on the problem of free will. 'All that the new physics has done', he says, 'is to break the fetters of materialistic determinism and pave the way for a more spiritual conception of causality.'[1] That, it might seem, is a good deal, if only one knew exactly how the new conception is 'more spiritual'. Mr. Morrison finds the problem to consist in the contradiction between God's preordaining what I do and my freedom. He puts the position quite clearly:

> It is best to state the antinomy with perfect frankness, as is done in the Westminster Confession which declares that God ordains whatsoever comes to pass, "yet so, as thereby neither is God the author of sin, nor is violence offered to the will of the creatures, nor is the liberty or contingency of second causes taken away, but rather established". And again, "God had endued the will of man with that natural liberty, that it is neither forced, nor by any absolute necessity of nature determined, to good or evil". In the famous Free Church Case Lord Haldane argued with great force and learning that the Confession taught at once Predestination and Free Will, and that both these doctrines were held by the Church, though to human view contradictory.

This attitude is interesting; to adopt it is consistent with Mr. Morrison's denial that recent physical speculations have in any way altered 'the problem of human free will'. It seems to me, however, that it is desirable to go further and to insist that no physical theories could have any bearing upon the problem, which is one for theology alone. Mr. Morrison says that in spite of Lord Haldane's 'great force and learning', his argument 'met with but scant consideration among the law lords, for the legal mind naturally abhors a break in the chain of reasoning'. This surprises me. I do not think that great learning is needed

[1] *Christian Faith and the Science of To-Day*, pp. 123 *seq.*

to discover that both Predestination and Free Will are taught in the Westminster Confession. Human beings do not find it difficult to slip into holding contradictory views. Mr. Morrison, however, reproaches the law lords for being 'strangely ignorant' that 'not in theology alone but equally in science and philosophy such antinomies abound'. He echoes once again Lord Balfour's too-oft quoted statement, 'the contradictions in theology are not more striking than the contradictions of science'. This *tu quoque* argument is surely deplorable. It is the last refuge of the weak. Nevertheless, it is a gain to be told clearly that predestination and human free will are in contradiction, or, in other words, that it is absurd to suppose that God my Creator can also rightly be my Judge. The State can rightly hold me to account in so far as the State did not create me.

I deserve punishment; it is fitting that I should be remorseful in so far as the evil that I do proceeds from what I am. It is *I* that am the *object* of punishment; it is *I* that am the *subject* of remorse. Just as it would be absurd to say 'an act is punished', so it is absurd to say 'an act is responsible' or 'an act is free'. The problem of freedom is the problem of the self.

Human freedom consists in this: that we do not yet know what we shall be, not because the knowledge is too difficult to acquire, not because there are no certainties but only very great improbabilities, but because we are not yet finished. We are begun; what we have already become and are now becoming plays a part in what we shall become. Nothing could be a more inadequate image for a human being than a pot or a machine, unless it be a hazy collection of qualities accidentally collocated and labelled with a name.

Part IV

THE CHANGED OUTLOOK

'It may be remarked that the main object of physical science is not the provision of pictures, but is the formulation of laws governing phenomena and the application of these laws to the discovery of new phenomena. If a picture exists, so much the better ; but whether a picture exists or not is a matter of only secondary importance. In the case of atomic phenomena no picture can be expected to exist in the usual sense of the word 'picture', by which is meant a model functioning essentially on classical lines. One may extend the meaning of the word 'picture' to include any *way of looking at the fundamental laws which makes their self-consistency obvious.* With this extension, one may acquire a picture of atomic phenomena by becoming familiar with the laws of the quantum theory.'

P. A. M. DIRAC

Chapter XI

ENTROPY AND BECOMING

'This is the way the world ends
This is the way the world ends
This is the way the world ends
Not with a bang but a whimper.'

T. S. ELIOT

EVERY scientist works in a context. To serve his special purpose he isolates certain factors present in the field of his investigation and studies these factors intensively. Frequently, and indeed usually, he isolates his study also from its history. This procedure undoubtedly has its uses. *Divide et impera* is a sound enough maxim. Scientific advance would be slow indeed were it not possible to secure a division of labour and a pooling of abilities; it would be a misfortune if the physicist had to combine in one not only 'the experimental physicist' and 'the mathematical physicist' but had further to make his own scientific instruments. But, useful though it is to rule by dividing, it is important not to forget that you have divided, if you seek to draw far-reaching conclusions from your investigation of the domain over which you have ruled. Nowhere does it seem, at least to the layman, that the danger of first isolating and then forgetting that you have isolated is more obvious than in some of the discussions in which physicists have indulged concerning the significance of the Law of Entropy. Edding-

ton's treatment of entropy and 'Time's Arrow' provides a glaring example of this mistake.

'From the point of view of philosophy of science', says Eddington, 'the conception associated with entropy must I think be ranked as the great contribution of the nineteenth century to scientific thought' (*N.Ph.W.* 103). This importance, on his view, is due to the fact that the law of entropy directed attention to 'qualities possessed by the system as a whole' instead of being confined to 'microscopic detail', and further, through the conception of entropy something was found 'to represent "becoming" in the physical world'. This conception, as Eddington points out, first 'secured a firm place in physics' because it was of importance in engineering. As originally conceived entropy is familiar to every one. You put your feet upon a hot-water bottle; after a short time your feet become warmer, the bottle becomes colder. You heat a poker red-hot and take it out of the fire; the poker becomes colder and the surrounding air becomes hotter. The reverse process does not happen.

We are so familiar with the fact that a hot body warms a colder one that we may forget that this result is in no way necessitated by the law of the conservation of energy. That heat is a form of energy and that energy is conserved constitutes what is known as the first law of thermodynamics. It is not at all incompatible with this law that a red-hot poker plunged into water should become hotter and the water colder. All that is required is that the amount of heat gained by the one body should equal the amount of heat lost by the other body. It does not happen that the hot body becomes hotter and the cold body becomes colder, but that it does not happen cannot be deduced from any fundamental physical laws.

The conservation of energy was first thought of as hold-

ing for mechanical phenomena. Mayer showed that a definite quantity of heat can always generate a definite quantity of work. Thus heat is recognized as a form of energy transformable into other forms of energy. Transformations of energy are not usually reversible ; energy tends to appear in less and less useful forms. The chemical energy of the mixture of petrol and air in the engine of a motor-car is transformed into intense heat and pressure ; it is thus utilizable for driving the car ; it may be transformed into heating the brakes. But the process is not reversible ; the heat in the brakes cannot be utilized to make petrol from the exhaust gases. In general other forms of energy than heat tend to be transformed into heat. The heat is dissipated, tending to be distributed evenly, the hotter bodies becoming colder and the colder ones less cold. This tendency was stated by Clausius as follows : ' It is impossible for a self-acting machine unaided by any external agency to convey heat from one body to another at higher temperature, or heat cannot of itself pass from a colder to a warmer body.' Heat processes, unlike mechanical processes, are uni-directional, i.e. irreversible.

The law stated by Clausius was the first statement of the second law of thermodynamics. It was developed without reference to the kinetic theory of heat, but later it was interpreted by means of the kinetic theory and it is to this interpretation that it owes its great importance. Boltzmann showed how the law could be deduced from the kinetic theory of heat by applying the statistical rules of the theory of probability. In a body of a given temperature slowly and rapidly moving molecules are mingled together. The measure of the temperature is the average velocity. If bodies of different temperature are brought into contact the molecules of which they are composed will collide. In

the case of each single collision all molecular velocities and all directions are equally probable: there will be a compensation of velocities. Thus the heat of the two bodies will tend to become the same; in other words, a condition of thermal equilibrium will tend to occur. The measure of this 'sameness' is called *entropy*. Maxwell defined entropy as that 'property of the body, expressed as a measurable quantity, such that when there is no communication of heat this quantity remains constant, but when heat enters or leaves the body, the quantity increases or diminishes'.[1] Thus the law of Clausius may be stated in the form: *The entropy of the system always tends to a maximum value.*

Boltzmann's interpretation of the second law of thermodynamics (now to be called 'the law of (increasing) entropy) is, I think, important for two reasons. First, it makes it clear that the law is a statistical law. We must not say that the passage from a colder body to a hotter is *impossible*, but only that it is *too improbable to happen*.[2] Secondly, since heat is energy in an unordered form as contrasted with the energy of mechanical work, the transformation of work into heat, and the dissipation of heat is seen to be the change from a relatively orderly to a relatively disorderly state. Hence, entropy is regarded as a measure of the random element in the world; increase of entropy is increase of

[1] *The Theory of Heat*, p. 61.

[2] Eddington lays great stress on this point. He says, 'I reckon a sufficiently improbable coincidence occurring within the supposed laws of Nature as more disastrous than an actual violation of the laws; because my whole reason for accepting the laws of Nature rests on the assumption that improbable coincidences do not happen—or at least they do not happen in my experience. No doubt coincidences described as "extremely improbable" occur to all of us, but the improbability is of an utterly different order of magnitude from that concerned in the present discussion' (*N.P.Sc.* 64).

disorganization. A state of maximum-entropy would be a state of thermal equilibrium ; there would be no variations of temperature, hence no changes could occur. At this point we add—' at least it is exceedingly unlikely that any changes would occur '. There are thus two extreme cases : maximum organization, or minimum entropy, i.e. no random element in the world ; minimum organization, or maximum entropy, i.e. thermodynamical equilibrium. The latter state is, Eddington says, a condition in which there is ' a fortuitous concourse of atoms '. It is evident that the world is not *now* in either of these states ; it is tending (according to the Law of Entropy) to the state of thermodynamical equilibrium, when energy will be evenly distributed. This will be ' the heat-death ' of the universe. This tendency is the ' running down of the universe ' which has so much dismayed philosophers and theologians. There must have been a state, prior to the state of the world as we know it, in which entropy was at a minimum so that there was the greatest possible unevenness in the distribution of energy. But since, according to the Law of Entropy, this state could not have succeeded a state of less entropy, there must have been a ' creation ' of the world at some date in the remote past or a world with minimum entropy must have begun spontaneously.[1] The former alternative, that the world was created by God at some definite time in the past is, Eddington

[1] Cf. Eddington : ' Travelling backwards into the past we find a world with more and more organization. If there is no barrier to stop us earlier we must reach a moment when the energy of the world was wholly organized with none of the random element in it. It is impossible to go back any further under the present system of natural law. I do not think that the phrase " wholly organized " begs the question. The organization we are concerned with is exactly definable, and there is a limit at which it becomes perfect. There is not an infinite series of states of higher and still higher organization ; nor,

says, 'the naïve theological doctrine which (suitably disguised) is at present to be found in every textbook of thermodynamics, namely that some billions of years ago God wound up the material universe and has left it to chance ever since' (*N.Ph.W.* 84).[1] This alternative is unacceptable to Eddington; so is the alternative that God created the world. 'As a scientist', he says, 'I simply do not believe that the present order of things started off with a bang; unscientifically I feel equally unwilling to accept the implied discontinuity in the divine nature.' His reluctance to accept either alternative, whilst realizing that, nevertheless, he can 'make no suggestion to evade the deadlock' (*N.Ph.W.* 85) is persistent. The following passage in *New Pathways of Science* brings out the nature of his difficulty very clearly:

> 'Philosophically the notion of an abrupt beginning of the present order of Nature is repugnant to me, as I think it must be to most; and even those who would welcome a proof of the intervention of a Creator will probably consider that a single winding-up at some remote epoch is not really the kind of relation between God and his world that brings satisfaction to the mind. But I can see no escape from our dilemma' (59).

It is not difficult to appreciate the nature of this dilemma. I have some sympathy with Mr. Braithwaite's remark; he says, 'if I believed in the second law of thermodynamics as much as Sir Arthur Eddington does, I should feel impelled to

I think, is the limit one which is ultimately approached more and more slowly. Complete organization does not tend to be more immune from loss than incomplete organization' (*N.Ph.W.* 84).

[1] Such a 'disguised' doctrine may perhaps be read into the following: 'In the world, order tends to degenerate spontaneously to chaos, and it requires effort to evolve order out of chaos' (Saha and Srivasta: *A Textbook of Heat*, p. 390). It is surely clear that the 'effort' required is not to be found within the 'chaos' but must be supplied from outside the system, i.e. from outside the World.

believe more than he does in an " incredible " First Cause ".'[1] But the difficulty is that the inference to a First Cause is not scientifically permissible, since the notion of an uncaused cause is not in conformity with the way in which a scientist makes use of causal laws. On the other hand, creation out of nothing by nothing is also a notion extraneous to science. The alternative method, namely, to attribute such creation to a genuine God working in a manner not comprehensible to scientists as such, is repugnant to Eddington personally since it involves a conception of God more appropriate to eighteenth-century Deism than to Christian Theism.[2] The fact that the law of entropy leads to the heat-death of the world does not in the least trouble him. 'It is curious', he says, 'that the doctrine of the running-down of the physical universe is so often looked upon as pessimistic and contrary to the aspirations of religion. Since when has the teaching that " heaven and earth shall pass away " become ecclesiastically unorthodox?' (59). Dean Inge, on the other hand, whilst agreeing that 'Christian Theism has always contemplated the final dissolution of the material universe'[3] feels that 'though God might exist without a world, it is difficult to imagine any reason why He should choose to create a world for a period only, and then destroy it'.[4] It seems that Dean Inge welcomes the acceptance of the law of entropy as providing further evidence of the futility of the nineteenth-century belief in a 'law of progress'—a belief against which he has constantly and violently protested. At the same time he feels 'that the sum of things should end in nothingness is a painful stultification of our belief in the values of life'.

In my opinion no arguments favourable to Christian

[1] *Mind*, N.S., 152, Oct. 1929, p. 419. [2] See *N.Ph.W.* 338.
[3] *God and the Astronomers*, p. ix. [4] *Ibid.*, p. 29.

beliefs can be drawn from the law of entropy, either with regard to the beginning of the world or with regard to its gradual and final degeneration into a condition of thermodynamical equilibrium. That a God such as a Christian could worship originally created this world is surely not to be inferred from the laws of physical phenomena.[1] That the Christian belief that 'heaven and earth shall pass away' is in conformity with the heat-death of the universe predicted by scientists as a consequence of the law of entropy should not, I think, be too easily assumed. It is a sign of the dominance of the scientists in our thinking to-day that many Christian apologists seem more concerned either to refute the second law of thermodynamics or to show that it is compatible with the teaching of Christ than to consider what kind of a world it is in which we—common readers and scientists alike—are living to-day. The discussion of this topic, however, belongs to the next chapter.

Eddington's main interest in the second law of thermodynamics is, I think, due to his desire to find something in the physical world to represent 'becoming'. To abandon this law, he says, 'means to uproot the signpost of time' (*N.P.Sc.* 61). This view seems to me to rest upon an incredible confusion. He apparently forgets that to each question investigated by a scientist there belongs its proper context, and to each answer to a question its appropriate degree of isolation within that context. It would be less absurd to say that time is abstracted from the passing of natural happenings than to say that entropy is the signpost of time.

Time is uni-directional, a one-way process; in other words, temporal process is irreversible. In the succession of events that constitutes Nature time is involved, and from that succession we derive our notion of time as uni-directional.

[1] See p. 285 below.

It is true that we have direct experience of 'becoming'. The passing from the past through the present to the future is fundamental to our experience. We can form no conception of what an experience would be like in which *has happened, is happening now, will happen* had not each its unique significance. For the purposes of describing, by mathematical equations, the ordinary processes of nature, excluding heat processes, these temporal determinations have no unique significance. In other words, the description of mechanical processes does not involve the direction of time; they are reversible. Eddington makes great play with the suggestion that if we were in an unfamiliar place undergoing unfamiliar experiences—'billions of miles from here, billions of years from now'—we should have difficulty in knowing which of these events in our experience were earlier and which later. From this dilemma entropy is invoked to save us. But Eddington has created a pseudo-difficulty, the source of which is not difficult to discover. His discussion of 'Time's Arrow' begins with the following significant statement:

> 'The great thing about time is that it goes on. But this is an aspect of it which the physicist sometimes seems inclined to forget. In the four-dimensional world . . . the events past and future lie spread out before us as in a map. The events are there in their proper spatial and temporal relation; but there is no indication that they undergo what has been described as "the formality of taking place", and the question of their doing or undoing does not arise. We see in the map the path from past to future or from future to past; but there is no signboard to indicate that it is a one-way street.' (*N.Ph.W.* 68.)

This statement is significant since it shows that Eddington has once again taken 'the symbolic world of physics' as complete in itself, in isolation from the processes whereby the physicist has been led to construct it, and has thus been

forced to look for some 'linkage' with the familiar world. 'It is an important question', he says elsewhere, 'whether consciousness in selecting its direction is guided by anything in the physical world' (*N.P.Sc.* 52). The question is not *important*; it is *absurd*. Consciousness does not *select* its direction but—to retain Eddington's mode of speaking—consciousness is directly aware of the succeeding of one event by another event. Assuming that consciousness has to select its direction, Eddington believes himself to be confronted with the problem: either consciousness is guided in its selection by something in the physical world or the distinction of future from past is merely subjective. Rightly rejecting the latter alternative Eddington pounces on entropy —the measure of the random element in the world—as affording a physical criterion by means of which we may discriminate the past from the future, the earlier from the later event. Increase of entropy is the arm of a signpost pointing 'To the Future'.

This is surely absurd. Eddington seems temporarily to have forgotten that the second law of thermodynamics is not an *a priori* principle but a well-established *experimental* law, 'very deeply rooted in physics'. He has forgotten that in order to discover the law scientists had to perform experiments. These experiments required that apparatus should be used by the experimenters, i.e. human beings; that observations should be made and recorded; that after these records had been interpreted the scientists had to formulate the law. But if increase of entropy is the criterion of the distinction of earlier from later, how was it discovered that entropy increases *as time goes on*? The experimental physicist had to remember the order in which he took the readings of his thermometers; that is, he had to know which record was the earlier, which the later, before he could

have detected that entropy increases in an irreversible direction. It is no answer to say, as Eddington would seem to do, that there are entropy-clocks in some portion of the experimenter's brain. 'Our consciousness', he says, 'somehow manages to keep in close touch with the material world, and we must suppose that its record of the flight of time is the reading of some kind of a clock in the material of the brain' (*N.Ph.W.* 100). This is no help, for these entropy-clocks measure 'the rate of disorganization of energy' and Eddington has distinguished between the increase of energy and the passage of time. There is no escape from the conclusion that the experimenter must be directly aware of the order of his observations.

This objection to Eddington's argument is so obvious that I might have supposed myself to have misunderstood him were it not for the fact that his difficulty is due to his conception of the symbolic nature of physics. His difficulty is to avoid ascribing too much to the work of the mind—'the editor in his sanctum'. 'If colour is mind-spinning', he says, 'so also is entropy a mind-spinning—of the statistician. It has about as much objectivity as a batting average' (95). Accordingly he strives to find in the experience of 'the editor himself' something that is not transmitted along the nerve fibres and there dressed up into a fanciful story, but is the direct equivalent of 'the time described in the messages' (100). Whereas colour is a symbol of electromagnetic waves that are symbols of an ultimate inscrutability, he maintains that 'becoming' is really a property in the world, and of this we have 'direct insight'. Thus *becoming* is known by a 'private door of the mind', not by the intervention of the nerve impulses. 'I grasp the notion of becoming', he maintains, 'since I myself become.' But since Eddington has completely severed 'the physical world'

from the Editor's story of it, he has to maintain that, apart from entropy, we could not know that the world has a history. I venture to think that this conclusion is as absurd as it sounds, and is due to the fact that Eddington has forgotten that the physicist works in the world, that his aim is to correlate our sensory experiences, and that, if in this work of correlation mathematical analysis is indispensable, it remains true that the final test of the success of the mathematical construction is in the experiments to which it leads and from which it started. The problem is not to be conceived as Eddington conceives it, namely, to construct a symbolic world and at the end raise 'the question of linkage'; the construction of the symbolic scheme is subsidiary to the task of co-ordinating our experiences and reducing them to order.

Chapter XII

INTERPRETATIONS

'Oh! that this too, too solid flesh would melt.'

SHAKESPEARE

THE two scientists with whose philosophical speculations we have been mainly concerned in the preceding chapters agree in thinking that the implications of contemporary theories of physics tend in the direction of idealism. Jeans, who believes it to be an advantage not to be trained in philosophy or to have an inclination for it if one wishes to draw philosophical conclusions from physics, seems nevertheless to have read both Plato and Berkeley. Evidently he has not studied any criticisms of either of these philosophers, and is consequently unaware that he has put forward views that have been seriously criticized—views that, in the opinion of most philosophers, have been decisively refuted. I do not intend to discuss these views further. Eddington is careful to tell us that 'the idealistic tinge' in his conception of the physical world 'arose out of mathematical researches on the relativity theory'. That this is so is, I think, evident to anyone who ponders his views. He has frequently pointed out his indebtedness to Bertrand Russell from whom he has accepted the nature of structure and has laid upon it a stress which it can hardly bear.

It is worth noticing that most physicists who have attempted

to construct a philosophy upon the basis of their physical researches have ended by elaborating some form of idealism. I at least have met none who have attempted to derive new arguments in favour of materialism. This is not true of the biologists but with them I am not here concerned. What is of interest for my purpose is to inquire what is the nature of the changes in physical conceptions that have seemed to support the conclusion that the implications of the physical world-picture are idealistic in trend? The answer to this question is probably obvious enough to anyone who has read the preceding chapters. There has been a profound reaction within the domain of physics itself against the too narrow conceptions and the too cocksure attitude of the nineteenth-century physicists. Advances in experimental technique and in mathematical methods have opened up fields of inquiry which were beyond the range of earlier investigators. The fundamental concepts of the Newtonian system have been radically revised. Above all, the kind of explanation of natural happenings that seemed satisfactory to the Victorian physicist has been completely abandoned. That these changes have come about as a consequence of the earlier developments of physics is sometimes forgotten and nearly always ignored. Moreover, the nineteenth-century physicist—with indeed notable exceptions—was prone to indulge in metaphysical speculations, even if he professed to disdain metaphysics. Contemporary physicists are apt to suffer from the same defect—a too hasty passage from physics to metaphysics.

Two main factors are responsible for the tendency of modern physicists to adopt some form of idealism. There is first the change in the conception of matter; secondly, the change in the status assigned by many physicists to natural laws.

Those who have sought to draw far-reaching philosophical conclusions from modern theories of matter have, it seems to me, not unfrequently fallen into gross confusions and have failed to take seriously the nature of the distinction between matter and mind, which elsewhere their philosophical theory requires them to accept. The way in which such confusions are generated and are made to seem enlightening is shown with unusual clearness in Mr. H. Stafford Hatfield's Preface to his translation of Dr. E. Zimmer's *The Revolution in Physics*. Having asserted that, in the attempt to relate physical formulae to reality, 'it is not the attitude of the physicist and the philosopher, but that of thinking mankind at large, that is of decisive importance', he proceeds to make a somewhat startling pronouncement:

> We are certainly assisting at the birth of a new era of human thought. We feel that it is to be an era of liberation, for we are very tired of the domination of the Machine, in spite of the wonderful progress it has inspired. For, ultimately, the classical picture of the universe is intolerable to man. It asks him to accept as the final reality a vast and sterile desert, in which the whole of his own history is an event as insignificant and momentary as the falling of a single drop of water upon the Sahara. This, we now know, is an appearance; reality cannot be described in terms of three-dimensional space and ever-flowing time. We are penetrating experimentally into its finest structure; we are finding perfect mathematical expression of our results. No machine-like picture can be constructed to fit these formulae, for they do not contain any mechanical elements. Therefore the machine was an illusion; we have thrust our fingers through it, and found it unsubstantial. But how was the illusion produced?

Whether 'thinking mankind at large' is to include the theologian is not very clear; presumably all non-scientific thinkers and the common reader are to be allowed to play a part in deciding whether or not a physical theory is to stand. If they find it intolerable, it must, presumably, be

rejected. No doubt we are tired of the domination of the machine although I am afraid that many of the advanced citizens of the world are not. Possibly Mr. Hatfield is referring to the dominance of the machine-image in our thinking. Whether we are tired of it or not certainly physicists no longer have any use for it. Although the machine may continue to dominate our lives the language appropriate to the behaviour of machines is not appropriate for the purposes of the physicist; it is out of date and has now been recognized to have been gravely misleading in the past. To have made this clear to the common reader is one great gain of the recent spectacular advances in physics and of the popularizations of them. Nevertheless, the conclusions that Mr. Hatfield draws from this change are startling. Without pausing to consider how it is possible to 'thrust our fingers through' an illusion, we may reasonably ask what there is in modern astronomical researches capable of assuring us that the history of mankind is not an insignificant event in the long history of the astronomical universe. If it lies within the competence of astronomers to inform us of significance or insignificance as touching the lives of men, the increasing importance attached to the law of entropy hardly suggests that there is ground for hopefulness. My own opinion is that it does not lie within their competence. I contend only that we cannot have it both ways. Either the decision whether our lives are significant does depend upon astronomical fact or it does *not*. If it does, then it is hard to see wherein modern astronomy justifies a cheerful view. If it does not, then equally Mr. Hatfield's conclusion does not follow.

However that may be, there can be no doubt of the striking change that has taken place in the physicist's conception of matter. Undoubtedly this change is important.

Important for whom, we may ask, since 'importance' is a term implying value and relevance to a purpose. Perhaps its main importance for the physicist as such is that it is now necessary for him to learn more, and more difficult, mathematical methods. That in itself is of no concern to the common reader. But 'the physicist himself' is an abstraction, and may well become a vicious abstraction. He also tends to have a philosophical outlook upon the world which —in some of its aspects—he is engaged in studying. There can be no question that physicists used to believe that matter consisted of little very hard lumps and that the modes of behaviour of these lumps could be exhaustively dealt with in accordance with the laws of mechanics. Hence arose the machine-image, the acceptance of strict and all-embracing determinism, and the Huxleian problem how men could nevertheless have ethical ideals directly opposed to the 'cosmic process' of which they were themselves parts. Huxley's contemporaries would certainly have tended to say that there were matter, electricity, and life—not to mention mind. Perhaps many of them believed that the two latter could be reduced to the former even if they were not quite sure how that reduction was to be achieved. In their unofficial moments they could hardly help noticing how great was the dissimilarity between a table and a flash of lightning, on the one hand, and a human person and his thinking, on the other hand—a dissimilarity which *prima facie* seemed so considerable as to make any theory of the relation between mind and body open to criticism. This dissimilarity of mind and matter, familiar to every student of philosophy since, at least, the time of Descartes and somewhat waveringly accepted by plain men, has been the source of philosophical controversies and the basis of many attempts to reduce matter to mind or to reduce mind to matter.

The latter attempt represents what is commonly called 'materialism', the former 'idealism'.

The terms 'materialism' and 'idealism' have, however, been used in a great variety of ways. Each has been applied to doctrines which are not consistent with one another, and few of which seem capable of being clearly stated. But so far as the common reader is concerned I think it may be taken for granted that materialism is understood to be the doctrine that matter alone is properly to be called 'real' and that minds are connected with living matter either as epiphenomena or in some other way consistent with the complete dependence of mind upon matter.[1] Idealism is popularly understood to be the view that mind alone is real and that material bodies are in some sense or other to be regarded as states of, or elements in, consciousness—either the consciousness of human beings or of God. This sharp-cut distinction between the two views is probably the heritage of the dualism introduced into modern philosophy by Descartes; this dualism is certainly wholly untenable in the form in which he held it.

So far as any form of materialism has drawn its inspiration from physical science, it may be said to have had two roots: belief in the universality of the laws in accordance with which material bodies behave and belief that matter is

[1] T. H. Huxley who, had he lived to-day, would possibly have regarded himself as an upholder of Naturalism, held views which were not easily to be distinguished from Materialism. Nevertheless, he vigorously repudiated the label. His essay 'Science and Morals'—which is nearly wholly polemical in tone—seems to me to show very well that Huxley was hardly capable of appreciating his opponent's point of view. (See *Evolution and Ethics*, pp. 137 *seq.*) I am aware that Huxley's curious mixture of Israelitish prophet, nineteenth-century journalist, and modern preacher is peculiarly repugnant to me. In consequence, I may unwittingly have been unfair to him.

permanent and indestructible. Tait, for instance, who seems to have combined a profound contempt for metaphysicians with a strong bias towards metaphysical speculations, asserted that 'we do not know, and are probably incapable of discovering what matter *is*',[1] but, elsewhere, he lays down confidently the criterion, 'the grand test of the reality of what we call matter, the proof that it has an objective existence, is its indestructability and uncreatability —if the term may be used—by any process at the command of man'.[2] The unphilosophically minded, however, have been mainly impressed by the solidity and impenetrability of matter, as evidenced by Samuel Johnson's striking his foot against a large stone. In comparison with the short span of human life the hills have seemed to be eternal. When reflexion suggested that even the hills 'wax old as doth a garment', scientists reinforced the belief in the permanence of matter by the discovery of the conservation laws. As the revolution in physics that has been held to complete the overthrow of materialism is a revolution against those physical theories which reached their final statement in the nineteenth century, it is sufficient for my purpose to try to evaluate, from the philosophical point of view, the nature of the change from the nineteenth- to the twentieth-century concept of matter.

The *solidity* of matter—that for the plain man has been its striking characteristic. 'Let us come to the solid rock of fact', 'A person of solid worth', 'A solid proposal'—these and a host of other metaphorical phrases, scarcely *felt* as metaphorical, testify to the importance attached to solidity in our imaginative thinking. The point need not be laboured. What is important is that the denial that matter is solid seems

[1] *The Properties of Matter*, § xx.

[2] *Recent Advances in Physical Science*, 1876, p. 14.

to the plain man to entail that matter is not real. By saying that matter is not real, the plain man means that matter is of no significance in 'the scheme of things'. It has been supposed that the outcome of modern physics involves the denial that matter is solid. It will suffice to consider one example of this line of reasoning, taken from Canon B. H. Streeter's book *Reality*, in which he offers 'A New Correlation of Science and Religion'.

The burden of Canon Streeter's argument is that, since matter is composed of electrons and protons, and since electrons and protons have been shown not to be solid, it follows that matter is not solid. But to the popular mind matter seems more real than thoughts because matter seems solid. But now that we know that matter is not solid, even though it may seem so, we no longer have any reason for supposing that matter is more real than thoughts. I do not think that my restatement is a travesty of his argument, but in order that the reader may not be misled I give the argument in full in the footnote.[1]

[1] '. . . it seems more probable than not that the electron should be regarded not as a "solid substance" at all but as a unit of electric force.

'Philosophers say that this discovery makes no difference at all to any conclusion they had previously held. I think they are right. But it does make a difference to popular materialism. To the popular mind—and all of us at times fall back to the level of popular thinking—the attractiveness of the theory that Matter is the prime reality, depends on the fact that life and thought are invisible, impalpable and evanescent, while material objects are not. If I thump on the ground with my stick, there is a solid reality which will outlast me and all my hopes and theories. But if matter is not solid at all—if in the last resort it can be resolved into infinitesimal points of electric force—it no longer strikes the imagination as being so much more real than invisibilities like life or thought' (op. cit., p. 16).

Canon Streeter quotes with approval a statement made by Bertrand

It seems to me that there are three insuperable objections to an argument of this form. First, the floor upon which I safely walk really is solid enough to be thumped by my stick, just as the plank of the threshold was solid enough to bear my weight as I entered the room and to support the chair upon which I sit. As we saw in Chapter III, unless the floor is solid, the word " solid " has no assignable meaning. Nothing about the floor or the stick has changed in consequence of physical discoveries. What has changed is not the nature of material objects, the familiar furniture of earth, but the scientific conception of ' matter '. That *solidity* is a property of a plank of wood which I sensuously apprehend when the electrons ' constituting ' my foot repel the electrons ' constituting ' the plank is a discovery of the physicists. This discovery does not in any way alter our sensuous apprehension of the objects of the familiar world, nor does it deprive the word " solid " of its common meaning and application. What has radically changed is the physicist's conception of the ultimate constituents of ' the world of physics '. This conception is often presented in a very misleading way. Thus, for example, Bertrand Russell says,

> Suppose that, with your eyes shut, you let your finger-tip press against a hard table. What is really happening ? The physicist says that your finger-tip and the table consist, roughly speaking, of vast numbers of electrons and protons ; more correctly, each electron and proton is to be thought of as a collection of processes of radiation, but we can ignore this for our present purposes. Although *you think you*

Russell in his Introduction to a new edition of Lange's *History of Materialism*. Speaking of the change brought about in the scientists' conception of matter by ' the merging of time into space-time '—in relativity theory—Russell said : ' A piece of matter has become, not a persistent thing with varying states, but a system of inter-related events. The old solidity is gone, and with it the characteristics that, to the materialist, made matter seem more real than fleeting thoughts.'

are touching the table, no electron or proton *in your finger* ever really touches an electron or proton in the table, because this would develop an infinite force.[1]

But, in such a case, you do not *think mistakenly* that you are touching the table; you really *are* touching the table, i.e. your *finger* touches the table. There is no mistake; you did not think that an electron 'in your finger' was touching an electron, nor is there any reason why you should so think. Presumably you did not know anything about electrons at all. *Touching* just is the experience you have when you press your finger (a macroscopic body) upon the table (another macroscopic body). Had you never had an experience of such a kind, you would not know what "touching" means. If you suppose that "touching" could be used in the same sense when speaking of electrons, then you would be making a grave mistake. But you do not suppose this. It is the philosophers of physics who make this mistake. Certainly, in so far as physicists and philosophers have drawn philosophical consequences from older scientific conceptions, or from mixing up the language appropriate to physics with the language appropriate to the familiar world, then these consequences stand in need of radical revision. But this is quite different from the contention that the floor can be 'resolved' into something that is not solid at all but is rather like life and thought.

Yet such misunderstandings constantly crop up. A recent example is to hand. The Rev. J. H. Morrison, in the course

[1] *An Outline of Philosophy*, p. 148 (italics mine). Cf. Max Born: *The Restless Universe*, p. 106.—'We think we see *things*, their outlines and colours.' Undoubtedly we see things. Not only is it true that I now see *the table* (and *the table* is a *thing*), but also that I am now *seeing*. Born emphasizes *things*; what does he suppose we *see* if not *things*, their *colours* and *outlines*? What sense can he give to 'see'?

of an argument designed to establish that 'at the heart of reality' there is a divine activity, an 'urge', a desire for 'self-completion' such as Aristotle's theology envisaged, says: 'All this is deeply in accord with some of the findings of the science of to-day. The new physics has done away with dead matter and introduced in its stead action as the ultimate physical reality, if physical it can be called.'[1] That '*action*'—in the physicists' sense, i.e. *momentum times distance*—could be regarded as equivalent to, or in any way analogous to, a desire, 'an urge towards the attainment of the ideal', 'a will to live', is simply absurd. But our concern is with the notion that *dead* matter has been done away with. I cannot suppose that Mr. Morrison would wish to deny the common-sense distinction between a dead lion and a living dog, nor that he would desire to suppress the burial service. I can only imagine that, on his view, what we *call* dead is nevertheless alive, although it has an appearance and behaves in a manner which *seem* to us incompatible with its being alive. Or is the opposite of 'dead matter' not *life* but something quite different? Perhaps Mr. Morrison does mean this, and that it is only the physicists who have 'done away with dead matter', and that the opposite of 'dead matter' is *momentum times distance*, i.e. action. It is difficult to tell. He does not pursue the argument, which is unfortunate. I must confess that I cannot see how 'action' in this highly technical sense can be regarded as having the slightest resemblance to desire or love. Indeed, I should have thought that a more hopeful line of argument for a Christian apologist, who wishes to bring the Christian faith into alignment with modern physics, would have been to insist upon the distinction between a dead body and a living body rather than to minimize it. Is there any evidence to

[1] *Christian Faith and the Science of To-day*, p. 212 (1936).

show that a living lion roaring after its prey can be brought within the physicist's scheme? No doubt many biologists and physicists believe that it will eventually be possible to do so, but, so far as I know, not even a beginning has yet been made in the accomplishment of this task.

The second objection to arguments of the form I have been considering is that the discovery that atoms are 'tenuous' was possible only because a piece of iron, for instance, is solid. This consideration deserves to be stressed, but it is not necessary that I should labour it further.[1]

The third objection is that to regard matter as tenuous—or to use an old-fashioned word 'ethereal'—is in no way to diminish the difference between the material and the mental. To suppose otherwise is surely a gross mistake, to which Bertrand Russell seems sometimes to lend countenance. I suspect that his argument that matter is more like mind and mind more like matter than has been supposed is merely his ironical way of suggesting that neither 'mind' nor 'matter' has any 'ultimate reality', and that both are arrangements of some neutral stuff that has all the disagreeable consequences of the 'matter' of the older materialistic view. That energy and radiation belong to the physical, i.e. the material, world is indisputable. Sunlight possesses inertia and is bent in a gravitational field. The discovery that matter, as regards its inertial property, is not different from sunlight does not in the least tend to abolish the distinction which we recognize between the mental and the material. Certainly we have no experience of mind apart from some manifestation in a material body; that, however, is no new discovery. It is hard to find any justification for maintaining that the distinction between the mental and the material has been abolished, or in any way lessened. Some

[1] See p. 130 above.

scientists, though not I think the physicists, would say that the difference is one of organization—a blessed word that covers a multitude of confusions. The organization, however, is of material bodies, not of immaterial minds or spirits.

Those who attempt to use the results of modern physics to support some form of philosophical Idealism or to find arguments for rejecting 'the classical picture' as being 'intolerable to man', come to a curious full stop. They do not consider whether the heat-death prophesied of the physical universe signifies a lowering of the vitality of mind—which, according to them, is what matter has become. Their jubilation does not seem to be damped by the reflexion that, whether or not the distinction between mind and matter has been abolished, lessened, or shown to be illusory, the future of the physical universe—i.e. the universe considered in physics—is presumed to be a uniform distribution of radiation. The law of entropy may serve to establish a God of sorts, but it does not afford any basis for supposing that what human beings most value will remain. The end of the world, according to the prophets of entropy, is too like a dead world to be worth calling by any other name.

The change in physics that is, in my opinion, important, is that physics has become more and more abstract in the course of its development and that physicists have now become aware (not to say sometimes 'obsessed') by this abstractness. Perhaps it would be more correct to say, not physicists, but mathematical physicists; possibly some only of these have been impressed by the abstractness of their knowledge about the world they investigate. The admission that physics is more abstract than had seemed to be the case has, unfortunately, been seized upon and misused

in a way similar to the misuse of the discovery that matter is electronic in structure. Not a few preachers have told their (largely ignorant) congregations that 'science has shown' that the chairs upon which they sit are *abstract*. This announcement brings the same sort of confused discomfort to some of their more intelligent hearers as statements to the effect that matter is rather like, if not identical with, light, and that love is 'at the heart of reality' because 'momentum times distance' has been called 'action'. The point, however, of saying that physics has become more abstract is only that the physicist is making ever more use of mathematical methods, that new forms of mathematics have had to be devised as the need for them arose, and, finally, that the results of mathematical physics can in no ordinary sense of the word 'picture' be pictured.[1] The day of mechanical models has gone by. In this sense, physics has 'become more abstract'.

There is another sense in which physics is, and has always of necessity been, abstract—namely, that the physicist deals with a selection of the properties of what there is in the world, and that his success in his investigation depends upon his isolating those properties and considering them on their own account. He has never been concerned with *chairs*, and it lies beyond his competence to inform us that the chairs we sit upon are abstract. Eddington thinks otherwise, for he believes that physics has shown that this chair is a schedule of pointer-readings. This view has already been dealt with. It must suffice here to assert that, in my opinion at least, modern theories of the atom afford not the slightest justification for saying that recent developments in physics have any tendency to show that materialism is false or are capable

[1] See the quotation from Dirac's *Principles of Quantum Mechanics* (p. 10), which forms the title-heading to Part IV.

of being used to provide any arguments in favour of idealism.

The change in the status assigned to physical laws is the second factor in 'the revolution in physics' that has been regarded favourably by idealists. It is indeed clear that this is the change that gave to Eddington's conception of the physical world that 'idealistic tinge' which was entirely different from the complexion of his earlier philosophical views. It is not at all surprising that Eddington, mathematician as well as physicist, gifted beyond the common race of physical scientists, and unshrinkingly aware of the gulf between our achievements and our hopes, should find in the theory of relativity a hint that the world we live in is made by mind. The way in which he has attempted to develop this view has been discussed in Chapter IV. Little more need be added here. It is enough to recall that Eddington has found in every fresh discovery in physics confirmation of the view he put forward in 1920 in *Space, Time, and Gravitation*. The latest statement of his view is worth quoting :

> Unless the structure of the nucleus has a surprise in store for us, the conclusion seems plain—there is nothing in the whole system of laws of physics that cannot be deduced unambiguously from epistemological considerations. An intelligence unacquainted with our universe, but acquainted with the system of thought by which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we have attained by experiment. He would not deduce the particular events and objects of our experience, but he would deduce the generalizations we have based upon them. For example, he would infer the existence and properties of radium, but not the dimensions of the earth.
>
> The mind which tried simultaneously to apprehend the complexity of the universe would be overwhelmed. Experience must be dealt with in bits ; then a system must be devised for reconnecting the bits, and so on. . . . In the end what we comprehend about the universe

is precisely that which we put into the universe to make it comprehensible.[1]

This passage admirably illustrates how wide is the divergence between Eddington's conception of Natural Law and that of the nineteenth century. I do not wish to minimize the importance of this change in the point of view. Still less do I wish to deny that 'there is nothing in the whole system of laws of physics that cannot be deduced unambiguously from epistemological considerations'. To do so would be a mere impertinence in a layman. Moreover, I must confess that the form in which Eddington has cast the great work from which this quotation is taken is delightful to me. But I am forced to ask whether, granting that such a deduction from 'epistemological considerations' be possible, there is any reason to believe that mind is the stuff of the universe. The answer, I think, is that there is not.

[1] *Relativity Theory of Protons and Electrons*, p. 319. Whilst these pages have been passing through the press an interesting discussion has been published in *Nature*, concerning the possibility of the *a priori* deduction of Laws of Nature. The discussion was provoked by an article, entitled 'Modern Aristotelianism', by Prof. Herbert Dingle (May 8, 1937), and is contained in a Supplement to *Nature*, June 12. Prof. Dingle criticized Prof. E. A. Milne's view, exemplified in his use of what he calls the 'Cosmological Principle', that 'it is, in fact possible to *derive* the laws of dynamics rationally . . . without recourse to experience' (see *Proc. Royal Society*, A. 158, 329; 1937); he commented also upon Eddington's statement, quoted above. Prof. Milne, Eddington, Dirac, and other distinguished scientists have commented upon Dingle's article. The reader will find the discussion amusing. It is interesting to note that Eddington concludes his comment with the remark that the (above) statement of his philosophy 'is not the basis but the unexpected conclusion of the investigation' (*loc. cit.* p. 1001.)

I am indebted to Dr. L. Hawkes for calling my attention to this discussion.

We are once again confronted with Eddington's failure to recognize the importance of the distinction between deductive physics and the experimental basis without which such deduction cannot even begin. He has once again confused 'the world of physics' with 'the physical world'. The former is to be found only in physics; it is the work of scientists; its form changes as fashions of thinking change and in accordance with the discoveries of the experimentalists. The latter, the physical world or Nature, is that *which physics is about*, and other sciences also are concerned with it. *This* does not change; there is no reason to suppose that *this* is created by physicists.

Eddington has amused himself by giving a description of 'the peculiar person called "the observer"', who has played so great a part in popular expositions of Einstein's theory of relativity. This observer has only one sense-organ, namely, a colour-blind eye, capable of seeing in only one direction at a time. He cannot perform the experiments himself since he is so poorly equipped with sense-organs, but he is allowed 'any number of assistants equipped like himself'. *We*, however, do in fact perform the experiments. 'The point', says Eddington, 'is that all our knowledge of the external world as it is conceived to-day in physics can be demonstrated to him. If we cannot convince *him* we have no right to assert it' (*N.P.Sc.* 13). I think that this story brings out with great clearness the merits and the limitations of Eddington's conception of physical knowledge. Certainly 'the peculiar observer' may be allowed to set the standard to which we must attain in any attempt to *demonstrate* our physical theories; these theories have been formulated by physicists in using a method of isolating the physical properties in the world from the sensory experiences of which they are properties. But the

peculiar observer is not capable of making the discoveries yielding the theories that are to be demonstrated. The peculiar observer, or an army of them, may be able to formulate Laws of Nature, i.e. symbolic physical schemes, but must wait upon the discovery of natural laws, i.e. generalizations of sensory recurrencies, in order that Laws of Nature may be suggested.

I find some support for this contention in the work by Dr. Zimmer, to which I have already referred, although I am not in general agreement with his philosophical outlook. He says :

> The search of the truth is carried on in small steps and is without end ; the theoretical ideas of the physicist die and are born whenever important new experimental discoveries are made. The discoveries of the experimental physicists are immortal, discoveries such as the diffraction of light by narrow openings, or the step by step emission of light of different colours which takes place when mercury atoms are bombarded with electrons of different speeds . . . All these are experimental facts which cannot be lost to us and always remain true. It is only our interpretation of these facts which passes and changes.[1]

The discoveries of the experimental physicists remain ; they are based upon inescapable facts. These discoveries are formulated in laws which are in no sense imposed by the mind of the discoverer. Diverse sets of natural laws are correlated and are co-ordinated in scientific schemes which are elaborated by the ingenuity of scientists. In this elaboration convention plays an important part ; the conventions of one age differ from those of another ; a convention is for use and may be dropped when it has outlived its utility. It is a characteristic of the present stage of physics that the part played by convention has come to be more and more clearly recognized. But not everything in science is conventional.

[1] *The Revolution in Physics*, p. 68. It must be noted that I quote from the English translation.

In my opinion the most pressing need in the philosophy of science at present is the determination of the scope of convention in science. I cannot make even an attempt to discuss this problem here. It would require another book, not so long as this one but much more technical. I must be content to point out that the theory of relativity has shown conclusively that there are no gravitational 'forces' in the world in the sense in which there are electric sparks. Thus the status of the law of gravitation has been profoundly modified. There is a profound, and I suppose, permanent change in our conception of the relation of mathematics to physics, a change that was undoubtedly initiated by Einstein's theory of relativity. In part this change consists in the recognition that mathematical structures, developed at first by pure mathematicians owing to the intrinsic interest of the subject, are capable of being used to illuminate the results of experimental physics. There is, I presume, no longer any hostility on the part of experimental physicists to the admission of purely mathematical concepts into the construction of Laws of Nature. Nevertheless, it remains true that the final test of a physical theory is to be found in the experimental results. The important, and in a way, too obvious and impressive, part played by mathematicians in physics must not blind us to the fact that the experimenter has to say the last words as well as the first.

I surmise that most physicists, in common with most plain men, take no interest either in philosophy in general or in the philosophy of science; they are all, however, intensely aware of the methods they employ and derive, I make no doubt, great satisfaction from the elegance of modern theories. Every scientist turned philosopher tends to find support in his special studies for the metaphysical theory which *on other grounds* he finds attractive. We have seen

that Jeans believes that 'the new physics' brings us hope since it 'has no longer any unanswerable arguments to bring against our innate conviction of free will', whilst Eddington believes that we need no longer doubt this intuition. Professor R. A. Millikan, on the other hand, has no desire to exalt the notion of caprice or to exult in the possibility that the world is fundamentally irrational. He believes that the 'two major contributions of science to human progress' are to be found in the conception of 'the reign of law', and in the idea of evolution. 'The ancient world', he says, 'in all the main body of its thinking, believed that God, or Nature, or the Universe, whichever term you prefer, was a being of caprice and whim. To-day, however, we think of a God who rules through law, or a Nature capable of being depended upon, or a Universe of consistency, of orderliness, and of the beauty that goes with order. This idea has *made* modern science, and it is unquestionably the foundation of modern civilization.'[1] He seems to think that the principle of uncertainty is 'consoling, or, at least, illuminating', if at all, then only 'to those non-physicists who have been worrying their heads over their inability to reconcile the principle of law with the facts of free will and of responsibility'. He suggests that since 'physicists have had much worse contradictions to put up with in the subjects of physics alone', they do not worry themselves about a possible conflict between free will and the reign of law. But, as we have seen, some physicists have been worried and have clutched the slender hope held out to them by the rejection of determinism. Professor Millikan's faith in the Christian religion is so robust and—in my opinion rightly

[1] *Forum*, Oct. 1929, article on 'What I Believe', p. 196. Cf. Millikan's interesting Terry lectures *Evolution in Science and Religion*, especially pp. 38–40.

—so independent of the outcome of physical speculations that he a little too hastily concludes that other physicists are in the same position. ' Eighteenth- and nineteenth-century materialism ', he proclaims, ' never had any lure for him [i.e. the physicist], for it always represented quite as pure dogmatism—assertiveness without knowledge—as did medieval theology, and modern developments have pushed it completely out of sight.' This is hardly true. To some physicists materialism has been ' a lure ', to others an oppression. Millikan is, however, in agreement with the physicists whom we have been considering in holding that materialism is now obsolete. His reason for this belief seems to be that the properties of the atom are now known to be ' quite as mysterious as any that used to masquerade under the name of " mind " '.

It is odd to find that the view that ' all is mysterious ' is to be regarded as a sign of hope. The rejection of the ' billiard-ball view ' of matter does not warrant the leap to any form of Idealism. Surely a view that finds a place for Mind in the universe only after the principle of uncertainty has been discovered or after abstruse physical speculations have made of physics a science not ' understanded of the people ' is not a view that should commend itself to the earnest seeker after God, especially if that seeker be a Christian. At least, I should have thought not, were it not that Christian apologists have been so eager to wait upon the pronouncements of the physicists, so thankful to be assured that *we* put into Nature the laws we profess to discover and, finally, that the chairs we sit on are not solid.

The common reader may well pause to ask why there is such anxiety to ' put Mind into Nature ' and to regard chairs as ' abstractions '. The world is what it is. Whether God or the physicists made it, or whether the language of

'making' is wholly inappropriate, does not affect the fact that men are capable of making a hell upon earth even though they can envisage something better. No doubt it is our realization of the gap between our ideals and our performance that makes us desire the assurance that 'at the heart of reality there is Spirit'. But the desire is irrational.

> 'Ah Love! could you and I with Him conspire
> To grasp this sorry Scheme of Things entire,
> Would we not shatter it to bits—and then
> Remould it nearer to the Heart's Desire!'

How does it help us to be told that 'the Scheme of Things' is created by God or imposed by Mind, if we find it to be 'sorry'? Is it not odd that men should have come to this pass—that they look for hope in physics and welcome, as some do, any indication of unreason in the world? Perhaps it seems less odd when we reflect upon the history of mankind, the hopeless mess that we have made of human lives. Our greed, our stupidity and lack of imagination, our apathy, these are the factors upon which the present sorry state of the world is largely consequent. It is enough to fill us with despair. Yet, despair need not be the last word. It lies within our power, if we so desire, to make the familiar world we inhabit more worthy of habitation by beings who aspire to be rational and are capable of love. Our limitation is due not to ignorance, not to the 'blind forces of Nature', not to the astronomical insignificance of our planet, but to the feebleness of our desires for good. This limitation is not to be removed by the advance of physical knowledge, nor should our hopes be placed in the researches of the physicist.

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