Quantum Physics and Theology

An Unexpected Kinship

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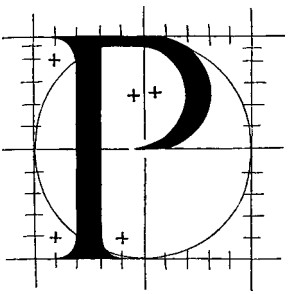
Contents

CHAPTER ONE

The Search for Truth



EOPLE sometimes think that it is odd, or even disingenuous, for a person to be both a physicist and a priest. It induces in them the same sort of quizzical surprise that would greet the claim to be a vegetarian butcher. Yet to someone like myself who is both a scientist and a Christian, it seems to be a natural and harmonious combination. The basic reason is simply that science and theology are both concerned with the search for truth. In consequence, they complement each other rather than contrast one another. Of course, the two disciplines focus on different dimensions of truth, but they share a common conviction that there is truth to be sought. Although in both kinds of enquiry this truth will never be grasped totally and exhaustively, it can be approximated to in an intellectually satisfying manner that deserves the adjective 'verisimilitudinous', even if it does not qualify to be described in an absolute sense as 'complete'.

Certain philosophical critiques notwithstanding, the pur-

suit of truthful knowledge is a widely accepted goal in the scientific community. Scientists believe that they can gain an understanding of the physical world that will prove to be reliable and persuasively insightful within the defined limits of a well-winnowed domain. The idea that nuclear matter is composed of quarks and gluons is unlikely to be the very last word in fundamental physics—maybe the speculations of the string theorists will prove to be correct, and the quarks, currently treated as basic constituents, will themselves turn out eventually to be manifestations of the properties of very much smaller loops vibrating in an extended multidimensional spacetime—but quark theory is surely a reliable picture of the behaviour of matter encountered on a certain scale of detailed structure, and it provides us with a verisimilitudinous account at that level.

Theologians entertain similar aspirations. While the infinite reality of God will always elude being totally confined within the finite limits of human reason, the theologians believe that the divine nature has been revealed to us in manners accessible to human understanding, so that these self-manifestations of deity provide a reliable guide to the Creator's relationship with creatures and to God's intentions for ultimate human fulfilment. For the Christian, this divine self-revelation centres on the history of Israel and the life, death and resurrection of Jesus Christ, foundational events that are the basis for continuing reflection and exploration within the Church, an activity that the community of the faithful believes to be undertaken under the guidance of the Holy Spirit. Revelation is not a matter of unchallengeable propositions mysteriously conveyed for the unquestioning acceptance of believers, but it is the record of unique

and uniquely significant events of divine disclosure that form an indispensable part of the rational motivation for religious belief.

Both these sets of claims for truth-bearing enquiry are made in conscious conflict with much of the intellectual temper of our time. In many parts of the academy the movement broadly called postmodernism holds sway. It emphasises what it sees as the uncertain basis of human knowledge, a vulnerability to challenge that results from the inescapable particularity of perspective imposed by the need to interpret experience before it can become intelligible and interesting. The necessary cultural context of language is held to imply that there is no universal discourse, but only a babble of local dialects. The grand modernist programme of the Enlightenment, alleged to be based on access to clear and certain ideas that are unquestionably acknowledged to be universally valid, is asserted to have been no more than the imposition of the perspective of white male Western thinkers, treated as if such attitudes were a non-negotiable rule for all. According to postmodernism, casting off these modernist shackles liberates twenty-first-century thinkers into being able to accept a creative plurality of ideas, thereby enabling participation in a conversation in which nobody's opinion has a preferred priority.

We certainly need to acknowledge that rational discourse is a more subtle matter than Enlightenment thinkers were able to recognise. Yet in the eyes of its practitioners, science does not at all look like a free market in ideas of an eclectic kind. We shall attempt to specify its character in more detail shortly, but one must begin by considering how it actually progresses. The more extreme postmodernists would challenge the use of that

last verb, but can one really suppose that the concepts of the helical structure of DNA and the quark structure of matter do not represent clear advances in understanding, intellectual gains that have become a persisting part of our understanding of the world? These ideas evolved under the irresistible nudge of nature, and not as fanciful notions whimsically adopted by the invisible colleges of molecular biologists and particle physicists respectively. Once the famous X-ray photographs taken by Rosalind Franklin had been seen and understood, there could be no doubt that DNA was a double helix. Once the data on hadronic structure (the patterns found in the properties of particles that make up nuclear matter), and the results of deep inelastic scattering (a particularly penetrating experimental probe), had been collected and assessed, there could be no doubt that fractionally charged constituents lay within protons and neutrons. Of course, interpretation was necessary—raw data such as marks on photographic plates are too dumb to speak of structure directly—but the naturalness of the interpretation, and its confirmation through a continuing ability to yield more understanding in the course of further lengthy investigations, is sufficient to convince scientists of the verisimilitudinous character of their theories. It is difficult for those not involved in scientific research to appreciate how difficult it is to discover theories that yield persistently fruitful and elegantly economic understanding of extensive swathes of experimental data, and therefore how persuasive such understandings are when they are attained. For those of us who were privileged to be members of the particle physics community during its twenty-five-year struggle to understand nuclear matter—an activity that eventually led to the Stan-

dard Model of quark theory[1]—the enterprise had precisely this convincing character. The experimentally driven investigation, often proceeding in directions quite different from the prior expectations of the theorists, was no indulgence in the construction of pleasing patterns, but it was the hard-won recognition of an order in nature that is actually there.

A just account of science lies, in fact, somewhere between the two extremes of a modernist belief in a direct and unproblematic access to clear and certain physical ideas, and a postmodernist indulgence in the notion of an à la carte physics. The intertwining of theory and experiment, inextricably linked by the need to interpret experimental data, does indeed imply that there is an unavoidable degree of circularity involved in scientific reasoning. This means that the nature of science is something more subtle and rationally delicate than simply ineluctable deduction from unquestionable fact. A degree of intellectual daring is required, which means that ultimately the aspiration to write about the *logic* of scientific discovery proves to be a misplaced ambition.[2] Yet the historical fact of the cumulative advance of scientific understanding implies that the circularity involved is benign and not vicious. In assessing the character of science and its achievements, we need to be sufficiently tinged with postmodernism to be able to recognise that there is a measure of rational precariousness involved in its interweaving of theory and experiment, but also sufficiently tinged with a modernist expectation of intellectual attainment to be able to do justice to science's actual success. The philosophical position that mediates between modernism

1. For a memoir of this period, see J. C. Polkinghorne, *Rochester Roundabout*, Longman/W. H. Freeman, 1989.

2. K. Popper, *The Logic of Scientific Discovery*, Hutchinson, 1959.

and postmodernism is commonly called critical realism, the adjective acknowledging the need to recognise that something is involved that is more subtle than encounter with unproblematic objectivity, while the noun signifies the nature of the understanding that it actually proves possible to attain.[3]

I believe that the philosopher of science who has most helpfully struck this balance has been Michael Polanyi. He knew science from the inside, since he was a distinguished physical chemist before he turned to philosophy. In the preface to his seminal book *Personal Knowledge*, Polanyi wrote,

> Comprehension is neither an arbitrary act nor a passive experience, but a responsible act claiming universal validity. Such knowing is indeed *objective* in the sense of establishing contact with a hidden reality . . . Personal knowledge is an intellectual commitment, and as such inherently hazardous. Only affirmations that could be false can be said to convey objective knowledge of this kind . . . Throughout the book I have tried to make this situation apparent. I have shown that into every act of knowing there enters a passionate contribution of the person knowing what is known, and this coefficient is no imperfection but a vital component in his knowledge.[4]

These convictions are worked out in great detail in the book, drawing on Polanyi's scientific experience in a way that other scientists can readily recognise as being authentic. He stresses not only commitment but also the tacit skills involved (for ex-

3. For more extended treatments of critical realism, see J. C. Polkinghorne, *One World*, SPCK/Princeton University Press, 1986, chs 1–3; *Reason and Reality*, SPCK/Trinity Press International, 1991, chs 1 and 2; *Beyond Science*, Cambridge University Press, 1996, ch. 2; *Belief in God in an Age of Science*, Yale University Press, 1998, chs 2 and 5.

4. M. Polanyi, *Personal Knowledge*, Routledge and Kegan Paul, 1958, pp. vii–viii.

ample, in evaluating the adequacy of theories and in assessing the validity of experiments in actually measuring what they are claimed to measure and not some spurious side-effects) that call for acts of judgement that cannot be reduced to following the rules of a specifiable protocol. The method of science has to be learnt through apprenticeship to the practice of a truth-seeking community, rather than by reading a manual of technique, for, in a phrase that Polanyi often repeated, 'we know more than we can tell'. This role for skilful judgement gives scientific research a degree of kinship with other human skilful activities, such as riding a bicycle or judging wine, that require the exercise of similarly tacit abilities. Though the subject of science is an impersonal view of the physical world, its pursuit is an activity of persons that could never be delegated simply to the working of a well-programmed computer. These personal acts of discovery are then offered for assessment and sifting within a competent community, whose judgements are made with the universal intent of gaining reliable knowledge of the physical world. The actual character of our encounter with that world remains the controlling factor. These last points save the personal knowledge of science from fragmenting into a loose collection of individual opinions.

I want to add a further note of a theological kind to the discussion, with the intent of making more intelligible this remarkable ability of scientists to gain such reliable knowledge of the universe, despite the degree of unavoidable epistemic precariousness involved in the endeavour. It is a fact of experience that this repeatedly proves possible, even for phenomena occurring in regimes that are remote from direct human encounter and whose understanding calls for ways of thought quite different from those of everyday life (quantum theory;

cosmology)—a fact, incidentally, that undermines the invocation of Darwinian evolutionary process as an all-sufficient explanation. The widespread success of science is too significant an issue to be treated as if it were a happy accident that we are free to enjoy without enquiring more deeply into why this is the case. Critical realist achievements of this kind cannot be a matter of logical generality, something that one would expect to be attainable in all possible worlds. Rather, they are an experientially confirmed aspect of the particularity of the world in which we live and of the kind of beings that we are. Achieving scientific success is a specific ability possessed by humankind, exercised in the kind of universe that we inhabit. I believe that a full understanding of this remarkable human capacity for scientific discovery ultimately requires the insight that our power in this respect is the gift of the universe's Creator who, in that ancient and powerful phrase, has made humanity in the image of God (Genesis 1:26–27). Through the exercise of this gift, those working in fundamental physics are able to discern a world of deep and beautiful order—a universe shot through with signs of mind. I believe that it is indeed the Mind of that world's Creator that is perceived in this way. Science is possible because the universe is a divine creation.[5]

In its turn, theology is not unacquainted with the necessity of circularity. Augustine and Anselm both emphasised the pattern of 'believing in order to understand' as well as 'understanding in order to believe'. No quest for truth can escape from the necessity of this hermeneutic circle, linking the encounter with reality to an interpretative point of view, so that they are joined in a relationship of mutual illumination and

5. Polkinghorne, *Belief in God*, ch. 1.

correction. Religious insight is not derived from the unhesitating acceptance of fideistic assertion (as if belief were simply imposed by some unchallengeable external authority, conveying to us indubitable propositions), but neither can it be based simply on argument controlled by the conventions of secular thought (such as, for example, the assumption of a purely naturalistic historicism that what usually happens is what always happens). Theology, as much as science, must appeal to motivated belief arising from interpreted experience. Of course, in the case of theology the kind of experience, and the kinds of motivated beliefs that arise from its interpretation, are very different from those appropriate to the natural sciences. The latter enjoy possession of the secret weapon of experiment, the ability to put matters to the test, if necessary through repeated investigation of essentially the same set of impersonal circumstances. This enables science thoroughly to investigate a physical regime defined by a definite scale (such as a given energy range) and to make an accurate map of it. From this ability arises much of the cumulative character of scientific understanding, a linear process in which knowledge increases monotonically. Even in sciences such as palaeontology, where scale is not a controlling factor and significant past events are not repeatable, evidence accumulates in forms that remain permanently accessible, to which direct recourse can be made for further assessment if required.

By way of contrast, in all forms of subjective experience —whether aesthetic enjoyment, acts of moral decision, loving human relationships, or the transpersonal encounter with the sacred reality of God—events are unique and unrepeatable, and their valid interpretation depends ultimately upon a trusting acceptance rather than a testing analysis. The pattern of

understanding that results is, so to speak, multidimensional rather than linear, with no necessary implication of a simple temporally ordered increase, as if the insights of the present were inevitably superior in all respects to the insights of the past. Four distinctive features of religious experience express the contrast between science and theology in these respects.

First, there is the fact, already noted, that the development of theological understanding is a more complex process than is the case for scientific understanding. Science achieves cumulative success, accessible in the present without a continual need to return to the past, so that a physicist today understands much more about the universe than Sir Isaac Newton ever did, simply by living three centuries later than that great genius. In religion, however, each generation not only has to acquire theological insight of its own and in its own way, but it also needs to be in a continuing active dialogue with the generations that have preceded it, lest the specific insights that they attained should be lost. In particular, the adherents of a faith tradition have to remain in permanent contact with that tradition's unique foundational events. While contemporary theologians enjoy the opportunities provided by the particular perspective of today, they need also to seek to correct any distortion produced by that perspective by being willing to learn from the complementary insights of earlier generations. All forms of encounter with deeply personal aspects of reality have to take this historical dimension seriously, for the character of their understanding is not simply cumulative, and evaluations need to be made in a living relationship with the past. Just as there is no presumptive superiority of twenty-first-century music over the music of past centuries, so there is no necessary superiority in every respect of the

ideas of the theologians of today over those of the fourth or sixteenth centuries. Just as philosophical dialogue today continues to engage with the ideas of Plato and Aristotle, in a similar way the great figures of the theological past—people such as Augustine, Aquinas, Calvin and Luther—remain necessary participants in contemporary conversation, in a way that Galileo, Newton and Maxwell are not so directly involved in the discourse of science. This is because the principal insights of those great scientific pioneers have been incorporated uncontroversially into present textbook knowledge. A purely contemporary judgement suffices. In the case of theology, however, the competent community within which insights are to be received and assessed is not simply the contemporary academy but it is the Church spread across the centuries. Hence the role of tradition, not as a straitjacket imposed a priori on current thinking, but as the indispensable resource for access to a reservoir of attained understanding which has continuing significance.

Second, in placing the physical world under scrutiny, whether by experiment or, in the case of historical sciences such as cosmology and evolutionary biology, by observation, the initiative for setting up this encounter with reality lies with the scientists. In the case of divine reality, however, God can take the initiative in conveying truth and, in fact, all religious traditions believe that this has happened in occasions of revelatory disclosure. One of the prime roles played by sacred scripture in the life of the traditions is to be the record of these theologically foundational events.[6] We have noted already that

6. For more on scripture, see Polkinghorne, *Reason and Reality*, ch. 5; *Science and the Trinity*, SPCK/Yale University Press, 2004, ch. 2.

for the Christian, basic sources of understanding centre on the revelation given in the history of Israel and in the life, death and resurrection of Jesus Christ, a point to which we shall make repeated return.

Making this second point draws our attention to a third difference between theology and science. The motivations for scientific belief arise principally from occurrences that, in principle, are publicly accessible and repeatable, with the consequence that science succeeds in eliciting virtually universal acceptance for its well-winnowed conclusions. Although in its modern form science got going in the particular time and place of seventeenth-century Europe, it has now spread world-wide. Once the dust has settled in some domain of scientific exploration, the insights that have been gained command universal respect and assent. Hence the unanimity, within the relevant competent communities, of belief in the helical structure of DNA and in the quark structure of matter. The religious scene, in contrast, is significantly fragmented. The great faith traditions, such as Judaism, Christianity, Islam, Hinduism and Buddhism, display considerable enduring stability within their adherent communities. They all claim to report and nurture human spiritual engagement with sacred reality, but there is also a perplexing degree of cognitive clash between them concerning detailed belief about the character of these encounters. These disagreements do not relate only to the defining convictions of the religions (such as Christian belief in Jesus as the Son of God, or Muslim belief in the absolute authority of the *Qur'an*), but they extend also to general metaphysical understandings. (Time: a linear pilgrim path, or a samsaric wheel from whose revolutions one needs to seek release? Human nature: qualities uniquely individual and

persistent, or recycled through reincarnation?) These clashes seem to exceed anything that could be explained simply as culturally diverse ways of expressing the same underlying truth. In this present book, whose purpose is to explore certain aspects of Christian belief and certain practices of Christian theology, I am not able to do more than acknowledge the challenging and perplexing nature of these interfaith disagreements. Their investigation is an increasingly important and active item on the theological agenda, but one that cannot be pursued further on this occasion.[7]

A fourth point of difference between theology and science relates to the consequences flowing from the embrace of belief. I am entirely convinced of the existence of quarks and gluons, but that belief, illuminating though it is in the limited sphere of elementary particle physics, does not affect my life in any significant way outside the pursuit of intellectual satisfaction in the study or the laboratory. In contrast, my belief that Jesus Christ is the incarnate Son of God has consequences for all aspects of my life, as much in relation to conduct as to understanding. Religious belief is much more demanding than scientific belief—more costly and more 'dangerous', one might say. This means that existential factors play a significant role in the way in which people approach the possibility of religious belief. The motivations that influence its acceptance will rightly include an assessment of the authentic humanity and life-enhancing influences to be found in the believing com-

7. For more on interfaith issues, see the tetralogy: K. Ward, *Religion and Revelation*, *Religion and Creation*, *Religion and Human Nature*, and *Religion and Community*, Oxford University Press, 1994, 1996, 1998, and 2000; also J. C. Polkinghorne, *Science and Christian Belief/The Faith of a Physicist*, SPCK/Fortress, 1994/1996, ch. 10.

munity. No one could suppose that making this assessment is an unambiguous and straightforward matter. The faiths have all at times been sources of conflict and oppression (as, of course, notoriously has also been the case for atheistic beliefs, such as those expressed in the regimes of Hitler and Stalin). Yet the faiths have also been sources of much human flourishing and centres of compassionate concern for the needy. In the case of Christianity, the dreadful history of crusades and inquisitions has to be held in tension with the Church's record in pioneering education and healthcare, the inspiration and support that it has given to so much achievement in art and music, and the work of many Christian people for peace and justice. There have certainly been ostensibly religious people whose lives have been denials of the values of the gospel, but there have also been many Christians whose lives have displayed outstanding integrity and love. We need to be thankful for St Francis as well as rightly being ashamed of Torquemada.

These four points of difference imply that the defence of critical realism is a more subtle matter in theology than it is in science. The diachronic character of theology, with insight spread across the centuries, deprives it of the simple appeal to manifest monotonic increase in understanding that is so persuasive in the case of science. Yet development and revision certainly occur in theology, as will be demonstrated by some of the illustrative material surveyed in the chapters that follow. Theologians seek to submit their thinking about the divine nature to being shaped by the character of God's revelatory self-disclosures, while acknowledging the ineffable element of mystery present in all human encounter with the Infinite. Thus I believe that theology can rightly lay claim to the

pursuit of truth under the rubric of critical realism. Moreover, it can appeal to a theological argument in support of that philosophical claim. The God of truth will not be a deceiver, and insights into the divine character, manifested either in the works of creation or in the events of revelation, can be relied upon not to mislead.

Thus, I see there to be a cousinly relationship between the ways in which theology and science each pursue truth within the proper domains of their interpreted experience. Critical realism is a concept applicable to both, not because there is some kind of entailment from method in one to method in the other—for the differences in their subject material would preclude so simple a connection—but because the idea is deep enough to encompass the character of both these forms of the human search for truthful understanding.

This is a theme that I have often discussed in my writing. Pursuing it requires the analysis of actual examples, rather than relying on an attempted appeal to grand general principles. In my Terry Lectures I sought to set out five points of analogy between two seminal developments, one in physics and one in Christian theology: the exploration of quantum insight and the exploration of Christological insight.[8] In making this comparison, I discerned five points of cousinly relationship between these two great human struggles with the surprising and counterintuitive character of our encounter with reality. In outline, these five points are:

(1) *Moments of enforced radical revision.* The crisis in physics that led eventually to quantum theory began with great

8. Polkinghorne, *Belief in God*, ch. 2.

perplexity about the nature of light. The nineteenth century had shown quite decisively that light possessed wave-like properties. However, at the start of the twentieth century, phenomena were discovered that could only be understood on the basis of accepting the revolutionary ideas of Max Planck and Albert Einstein that treated light as sometimes behaving in a particle-like way, as if it were composed of discrete packets of energy. Yet the notion of a wave/particle duality appeared to be absolutely nonsensical. After all, a wave is spread out and oscillating, while a particle is concentrated and bullet-like. How could anything manifest such contradictory properties? Nevertheless, wave/particle duality was empirically endorsed as a fact of experience, and so some radical rethinking was evidently called for. After much intellectual struggle this eventually led to modern quantum theory.[9]

In the New Testament, the writers knew that when they referred to Jesus they were speaking about someone who had lived a human life in Palestine within living memory. Yet they also found that when they spoke about their experiences of the risen Christ, they were driven to use divine-sounding language about him. For example, Jesus is repeatedly given the title 'Lord', despite the fact that monotheistic Jews associated this title particularly with the one true God of Israel, using it as a substitute for the unutterable divine name in the reading of scripture. Paul can even take verses from the Hebrew Bible that clearly refer to Israel's God and apply them to Jesus (for example, compare Philippians 2:10–11 with Isaiah 45:23, and 1 Corinthians 8:6 with Deuteronomy 6:4). How could this

9. For an introduction to quantum theory, see J. C. Polkinghorne, *Quantum Theory: A Very Short Introduction*, Oxford University Press, 2002.

possibly make sense? After all, Jesus was crucified and Jews saw this form of execution as being a sign of divine rejection, since Deuteronomy (21:23) proclaims a curse on anyone hung on a tree. Experience and understanding seemed as much at odds here as they did in the case of the physicists' thinking about light.

(2) *A period of unresolved confusion*. From 1900 to 1925, the physicists had to live with the paradox of wave/particle duality unresolved. Various techniques for making the best of a baffling situation were invented, by Niels Bohr and others, but these expedients were no more than patches clapped onto the broken edifice of Newtonian physics, rather than amounting to the construction of a grand new quantum building. It was intellectually all very messy, and many physicists at the time simply averted their eyes and got on with the less troubling task of tackling detailed questions that were free from such fundamental difficulties. Problem-solving in normal science is often a more comfortable pursuit than wrestling with perplexities in revolutionary science.

In the New Testament, the tension between human and divine language used about Jesus is simply there, without any systematic theological attempt being made to resolve the matter. It seems that those early generations of Christians were so overwhelmed by the new thing that they believed that God had done in Christ, that its authenticity and power were of themselves sufficient to sustain them without forcing them to attempt an overarching theoretical account. Yet, the position taken by those New Testament writers was clearly intellectually unstable, and the issue could not be ignored indefinitely.

(3) *New synthesis and understanding.* In the case of physics, new insight came with startling suddenness through the theoretical discoveries of Werner Heisenberg and Erwin Schrödinger, made in those amazing years, 1925–26. An internally consistent theory was brought to birth, which required the adoption of novel and unanticipated ways of thought. Paul Dirac emphasised that the formal basis of quantum theory lay in what he called the superposition principle. This asserts that there are quantum states that are formed by adding together, in a mathematically well-defined way, physical possibilities that Newtonian physics and commonsense would hold to be absolutely incapable of mixing with each other. For example, an electron can be in a state that is a mixture of 'here' and 'there', a combination that reflects the fuzzy unpicturability of the quantum world and which also leads to a probabilistic interpretation, since a 50–50 mixture of these possibilities is found to imply that, if a number of measurements of position are actually made on electrons in this state, half the time the electron will be found 'here' and half the time 'there'. This counterintuitive principle just had to be accepted as an article of quantum faith. Richard Feynman introduced his lectures on quantum mechanics by talking about the two-slits experiment (a striking example of counterintuitive quantum ambidexterity), concerning which he wrote,

> Because atomic behaviour is so unlike ordinary experience, it is very difficult to get used to, and it appears peculiar and mysterious to everyone . . . we shall tackle immediately the basic element of the mysterious behaviour in its most strange form. We choose to examine a phenomenon which is impossible, *absolutely* impossible, to explain in any classical way, and which has in it the heart of

> quantum mechanics. In reality it contains the *only* mystery. We cannot make the mystery go away by 'explaining' how it works. We will just *tell* you how it works.[10]

The quest for a deeper understanding of the fundamental phenomena recorded in the New Testament, eventually led the Church to a trinitarian understanding of the nature of God (Councils of Nicaea, 325, and Constantinople, 381) and to an incarnational understanding of two natures, human and divine, present in the one person of Christ (Chalcedon, 451). These were important Christian clarifications, but one cannot claim that theology, wrestling with its profound problem of understanding the divine, has been as successful as science has been in attaining its understanding of the physical world. The latter is at our disposal to interrogate and put to the experimental test, but the encounter with God takes place on different terms, involving awe and worship and obedience. There is an important qualifying theological insight, called apophatic theology, stressing the otherness of God and the necessary human limitation in being able to speak adequately of the mystery of the divine nature. There are bounds to the possibilities of theological explanation. The Fathers of the Church, who at the Councils had formulated fundamental Christian insights, would, I believe, have been quite content to echo Feynman's words, 'We will just *tell* you how it works'.

(4) *Continued wrestling with unsolved problems.* Even in science, total success is often elusive. Quantum theory has been brilliantly effective in enabling us to do the sums, and their

10. R. Feynman, *The Feynman Lectures on Physics*, vol. 3, Addison-Wesley, 1965, p. 7.

answers have proved to be in extremely impressive agreement with experimental results. However, some significant interpretative issues still remain matters of uncertainty and dispute. Chief among these is the so-called measurement problem. How does it come about that a *particular* result is obtained on a particular occasion of measurement, so that the electron is found to be 'here' this time, rather than 'there'? It is embarrassing for a physicist to have to admit that currently there is no wholly satisfactory or universally accepted answer to that entirely reasonable question. Quantum physics has had to be content for eighty years to live with the uncomfortable fact that not all its problems have yielded to solution. There are still matters that we do not fully understand.

Theology also has had to be content with a partial degree of understanding. Trinitarian terminology, for example in its attempt to discriminate the divine Persons in terms of a distinction between begetting and procession, can sometimes seem to be involved in trying to speak what is ineffable. The definition of Chalcedon, asserting that in Christ there are two natures 'without confusion, without change, without division, without separation', is more a statement of criteria to be satisfied if Christological discourse is to prove adequate to the experience preserved in scripture and continued within the Church's tradition, than the articulation of a fully developed Christological theory. Chalcedon maps out the enclosure within which it believes that orthodox Christian thinking should be contained, but it does not formulate the precise form that thinking has to take. In fact, further Christological argument, both within the Chalcedonian bounds and outside them, has continued down the centuries since 451.

(5) *Deeper implications.* A persuasive argument for a critical realist position lies in its offering an explanation of how further successful explanations can arise from a theory, often concerning phenomena not explicitly considered, or even known, when the original ideas were formulated. Such persistent fruitfulness encourages the belief that one is indeed 'on to something', and that a verisimilitudinous account has been attained. In the case of quantum theory, a number of successes of this kind have come to light, including explaining the stability of atoms (their remaining unmodified by the numerous low-energy collisions to which they are subjected), and the very detailed calculations of their spectral properties that have proved to be in impressive agreement with experimental measurements. Strikingly novel, and eventually experimentally verified, predictions have also been made. One of the most outstanding of these is the so-called EPR effect, a counterintuitive togetherness-in-separation that implies that two quantum entities that have interacted with each other remain mutually entangled, however far they may subsequently separate in space. Effectively, they remain a single system, for acting on the one 'here' will produce an immediate effect on its distant partner.

Incarnational belief has offered theology some analogous degree of new insight. For example, Jürgen Moltmann has made powerful use of the concept of divine participation in creaturely suffering through the cross of Christ. He emphasises that the Christian God is the crucified God,[11] the One who is not just a compassionate spectator of the suffering of creatures but a fellow-sharer in the travail of creation. The

11. J. Moltmann, *The Crucified God*, SCM Press, 1974.

concept of a suffering God affords theology some help as it wrestles with its most difficult problem, the evil and suffering present in the world.

The purpose of this book is to pursue further the analogies between the scientific investigation of the physical world and theological exploration of the nature of God. This strategy is adopted in the hope that it will encourage those of a scientific cast of mind to take theological discussion more seriously, and that it will also offer theologians a worked example of a form of possible approach to theological enquiry of a form naturally congenial to the scientifically minded, moving from experience to understanding in a manner that I have called 'bottom-up thinking'.[12] The procedure that I shall follow is to set up a series of parallels between aspects of exploration and conceptual development as we find them respectively in quantum physics and in Christian theology.

12. For an approach to Nicene Christian belief along these lines, see Polkinghorne, *Science and Christian Belief/Faith of a Physicist.*