

The New Physics and Opportunities for Ontological Initiatives

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In this Section of the Conference we are making what one might call a voyage from physics to metaphysics, using 'physics' in its ancient sense of what concerns the nature of things, and concentrating on those aspects of things that are disclosed by the natural sciences. The traveller on such an intellectual expedition has a choice of routes and end-points, for metaphysical views are selected and defended for metaphysical reasons, and no metaphysical view can claim the degree of coerciveness that would correspond to logical necessity. The relation between physics and metaphysics is a subtle one and there is no inescapable entailment linking the two. Yet, physics constrains metaphysics, rather as the foundations of a building constrain, but do not determine, the edifice that can be erected upon them. The connection between the scientific concepts of physics and the philosophical or theological concepts of metaphysics, is that of an alogical association, based upon a perceived consonance. I believe that modern physics has opened up a significant number of possibilities for fruitful metaphysical construction which I shall seek briefly to explore. A sub-theme in what I have to say will be that a theistic metaphysics has attractive insights to offer, but this is not an occasion on which I shall try to analyse in any detail the relationship between science and theology. There are seven scientifically disclosed aspects of our universe to which I want to draw attention:

(1) *A Deeply Intelligible Universe*. It is scarcely surprising that we can understand the world in the everyday way that is obviously necessary for our survival within it. If we could not figure out that it is a bad idea to step off the top of a high cliff, we would not be around for very long. But it does not follow from this that someone like Isaac Newton could come along and, in an astonishing creative leap of imagination, see that the same force that makes the cliff dangerous is also the force that holds the Moon in its orbit around the Earth and the Earth in its orbit around the Sun, discover the beautiful property of universal inverse square law gravity, and so make comprehensible the behaviour of the whole solar system. The developments of modern science have shown us that human scientific ability far exceeds anything that could reasonably be considered as simply an evolutionary necessity, or as a

happy spin-off from it. The universe has proved to be astonishingly rationally transparent, and the human mind remarkably apt to the comprehension of its structure. We can penetrate the secrets of the subatomic realm of quarks and gluons, and we can make maps of cosmic curved spacetime, both regimes of no direct practical impact upon us, and both exhibiting properties that are counterintuitive in relation to our ordinary habits of thought. Our understanding of the workings of the world greatly exceed anything that could be necessary simply for survival.

It has also turned out that it is mathematics that is the key to unlocking these scientific secrets. In fundamental physics it is an actual technique of discovery to look for equations that have about them the unmistakable character of mathematical beauty. Time and again we have found that it is only equations of this kind that will prove to be the basis for theories whose long-term fruitfulness convinces us that they are indeed verisimilitudinous descriptions of physical reality. The greatest physicist whom I have known personally, Paul Dirac, one of the founding figures of quantum theory, once said that it was more important to have mathematical beauty in one's equations than to have them fit experiment. Of course, Dirac did not mean that empirical success was an irrelevance in physics - no scientist could believe that. Yet, if at first sight one's equations did not appear to fit experiment, there were some possible ways out of the difficulty- maybe you had not solved them correctly, or maybe the experiments themselves were wrong - but if the equations were ugly ... well, there was really no hope for them. Dirac made his many great discoveries by a lifelong and highly successful quest for mathematical beauty.

When we use abstract mathematics in this way, as a guide to physical discovery, if we stop to think about it we shall see that something very odd is happening. After all, mathematics is pure thought and what could it be that links that thought to the structure of the physical world around us? Dirac's brother-in-law, Eugene Wigner, who also won a Nobel Prize for Physics, once called this 'the unreasonable effectiveness of mathematics'. He also said it was a gift that we neither deserved nor understood.

Well, I would like to understand it. It would be too intellectually lazy just to say, 'That's the way it is - and a bit of good luck for you people who are good at mathematics !'. If I am to gain that understanding, I shall have to look outside of science itself, for the latter is just glad that it is so and then gets on with the task of exploiting the opportunities that it offers. If one is imbued with that thirst for understanding so typical of the scientist, then one will want to face the fact that science is privileged to explore a universe that is both rationally transparent to us and rationally beautiful in its deep order. It does not seem sufficient just to treat this as a happy accident. Scientists frequently speak of the experience of wonder as the reward for all the weary labour involved in their research. Something deep is going on in science' 5 exploration of our profoundly intelligible universe that calls for further illumination.

It seems to me that a purely naturalistic metaphysics is unable to cast light on this deep intelligibility, for ultimately it has to treat it as a fortunate but fortuitous fact. Here is the first point of my discussion where a theistic metaphysics has something extra to offer, for it suggests that the reason within our minds, and the rational structure of the physical world around us, have a common origin in the rationality of the God who is the ground both of our mental and of our physical experience. In Christian theological terms, our scientific ability to explore of the rational beauty of the universe is part of the deposit of the *imago dei*. Putting the matter in the simplest terms, science encounters a universe whose beautiful rational order is that of a world shot through with signs of mind, and it is surely worth considering whether it might not indeed be the Mind of the Creator that is thus discerned.

(2) *A Universe with a Fruitful History*. We have heard earlier in this conference how the universe as we know it originated in the fiery singularity of the big bang, some thirteen billion years ago. It started extremely simple, just an almost uniform expanding ball of energy. After thirteen billion years of evolving history, the universe has become richly diverse and structured, with ourselves the most complex consequences of which we are aware. In one of his books, Holmes Rolston tells us that when an astronomer peers through a telescope at some distant galaxy, he or she should remember that the most complex physical

structure we have ever encountered is just six inches this side of the eyepiece - the human brain within the skull of the astronomer. It is a striking fact that the initial ball of energy has become the home of saints and mathematicians. This recognition in itself might raise the metaphysical question of whether there has not been more going in cosmic history than science alone can fitly express.

Of course, the universe's history has been an evolving history, as much on the cosmic scale as it has been in relation to the development of biological life on Earth. As we think about that fact, we may indeed follow the distinguished French biochemist and atheist, Jacques Monod, in seeing evolutionary process as involving an interplay between chance and necessity, but we need not go on to agree with him in annexing the metaphysically tendentious adjective 'blind' to the chance half of the process. By 'chance' is not meant the operations of the capricious goddess Fortuna but, rather, historical contingency, that this happens rather than that. This particular genetic mutation turns the stream of life in this particular direction. Had a different mutation occurred instead, a different possibility would have been realised. Not everything that could happen, has happened; history necessarily represents only a small selection from the range of possibility. Chance, therefore, is a shuffling mechanism for exploring potentiality. Of course, genetic mutations are blind to the pressures of changing environmental circumstances, but they are a subtle means by which life can adapt itself to those circumstances. Theologically understood, this is the way in which creatures are allowed by their Creator 'to make themselves'. Theology does not need to see the history of the world as the performance of a fixed score, written by God from all eternity, but it may properly understand it as the unfolding of a grand improvisation in which the Creator and creatures both participate.

Evolution happens within the given necessity of natural law, a point too little attended to by Monod. As we have heard earlier in the Conference, in recent years the collection of scientific insights called the Anthropic Principle has led us to the surprising conclusion that a universe capable of evolving the complexity of life as we know it, is a very special world indeed. While the contingency of evolutionary process is certainly part of the cosmic story, it is only one aspect, and the proper understanding of that story requires the recognition of the

'fine-tuning' of the lawful necessity of the world, which has also been an indispensable element in what has been going on. While life only appeared when the universe was about ten billion years old, and self-conscious life when it was thirteen billion years old, there is a real sense in which the universe was pregnant with carbon-based life almost from the moment of the big bang onwards. Its physical fabric was then of the precise kind that alone would allow this possibility eventually to come about.

Many scientists were upset when this remarkable specificity of our universe was recognised. They did not like the thought that there was anything special about our world, for they would have preferred to consider it as being just a typical specimen of what a universe might be like. The scientific instinct is unnecessarily wary of the unique. A modest relaxation of anxiety can be achieved by recognising that, if the process of the universe is described by an appropriate Grand Unified Theory (GUT), whatever that may prove to be, it is may well contain large inflated cosmic domains in which spontaneous symmetry breaking, reducing the ur-forces of the GUT to the observed forces at work in nature today, has given different ratios for the effective coupling constants operating at the energies important for cosmic processes after the first three minutes. We of course, must be living in that domain where these ratios permit the possibility of carbon-based life. However, this proposal, which I accept as being an entirely credible possibility, only relaxes anthropic specificity to a modest degree. One still requires the primeval GUT to be capable of generating the right sort of inflation and the right sort of symmetry breaking, able in some domain to reduce to the anthropic balances that we actually observe. The universe would still be far from being just 'any old world'. Those who wish to define anthropic uniqueness more drastically, are driven to the prodigal supposition that there is a truly vast portfolio of other universes, all with greatly different sorts of natural laws and circumstances and all, of course, inaccessible to us. Our universe is then just the one where fortuitously carbon-based life is possible, a winning ticket in a multi-cosmic lottery. This proposal of a prodigious multiverse is not a scientific suggestion but a metaphysical speculation, a way to accommodate anthropic fine-tuning within a prodigally enlarged naturalism. It seems to me that a much more economic

understanding is offered by the belief that there is only one universe, which is the way it is because it is indeed not 'any old world' but a creation that has been endowed by its Creator with just those finely-tuned laws that have enabled it to have a fruitful history. Like all metaphysical discussion, the argument is not of a logically coercive, knock-down kind, but for me it is coherent and intellectually satisfying. In particular, belief in God the Creator does a whole number of other pieces of explanatory work, such as enabling us to understand the universe's deep intelligibility and the origin of the widely attested human experience of encounter with the sacred. On the other hand, the many-universes hypothesis seems to do only one piece of explanatory work, namely granting relief from taking seriously the possibility of theism. I do not think that William of Ockam would have been happy with such a rash multiplication of entities.

(3) *A Relational Universe*. Newtonian physics pictured the collisions of individual atoms as taking place within the container of absolute space and in the course of the unfolding of a universal absolute time. Einstein's theories of special and general relativity showed that space, time and matter are intimately interconnected in a kind of package deal, in which matter curves spacetime and spacetime curves the paths of matter. Later Einstein, through the discovery of the EPR effect, showed that quantum theory implied that once two quantum entities have interacted with each other they remain mutually entangled however far they may eventually separate. This counterintuitive togetherness-in-separation seemed so 'spooky' to Einstein that he supposed it indicated that there was something incomplete in the quantum account. However, the beautiful experiments of Alain Aspect and his collaborators have shown us that non-locality is indeed a property of nature. It has turned out that even the subatomic world cannot be treated atomistically. Twentieth century science revealed a deep seated relationality present in the fabric of the physical world.

I do not think that metaphysical thinking has yet totally absorbed these developments or come to terms with the fact that localised individuality is no longer an unproblematic concept. Here is an opportunity for important further developments in ontological thinking, that we may hope will be

grasped in the course of the twenty-first century. It is striking that so methodologically reductionist a subject as physics has pointed us in this holistic direction. This tendency is surely reinforced by chaos theory's discovery that at the macroscopic level of physical process there are many systems which are of such exquisite sensitivity to the details of their circumstance that they cannot properly be isolated from the effects of their environment. Of course, experimental exploration has tended to concentrate on the investigation of those situations where isolatability is an acceptable idealisation. Otherwise one would have to understand everything before one could understand anything. However, the general character of physical reality seems to have a much more web-like character of irreducible integrity. An ontological possibility that needs serious consideration is that the detailed character of the laws of nature that we have formulated on the basis of isolatable experimentation are no more than what one might call 'downward-emergent' approximations to some more holistic account of physical reality.

Perhaps I may permit myself two wider metaphysical comments before I leave this topic. One is that if physics is moving in a more holistic direction, we might expect by analogy to need to challenge the individualistic atomism that is so characteristic of contemporary thinking about human nature. If electrons are counterintuitively entangled with each other, we may need to contemplate the possibility that persons are part of some greater solidarity, of a kind that the insights of some forms of depth psychology or of tribal societies may give us some clue to beginning to understand. The other comment is to note that the Christian insights of Trinitarian theology affirm that the Ground of all reality is also relational, in the perichoretic exchanges between the Divine Persons. An excellent contemporary work on Trinitarian theology is entitled *Being as Communion* (John Zizioulas). One could paraphrase that as 'Reality is relational'.

(4) *A Universe of Veiled Reality*. Although the world appears so clear and reliable in terms of our everyday experience, quantum theory has shown us that it is cloudy and fitful at its subatomic roots. Whatever interpretation of quantum theory one may embrace, common to all is the realisation that Heisenberg's uncertainty principle sets limits to our epistemic access to knowledge of what is going on. Whether this is due to unfortunate ignorance of hidden detail, as David Bohm believed, or

whether it is an intrinsic ontological property of subatomic reality, as conventional quantum theory asserts, is still a matter of dispute. The empirical equivalence of the predictions of Bohmian theory and of conventional quantum theory imply that the issue is metaphysical in character and so it lies beyond simple possibility of experimental settlement. If one adopts the view, first commended by Werner Heisenberg, that one should consider the quantum world as a realm of potentialities which can only become fleeting actualities as a result of experimental interrogation, then its reality must take an idiosyncratically veiled form. I shall not elaborate much further here, since the chairman of our session has himself written so helpfully about these issues, but it is clear enough that even Bernard d'Espagnat has not written the last word and that important metaphysical discussions will continue concerning the nature of quantum ontology. Let me be content with two additional comments.

Most physicists remain convinced that the word 'reality' is the correct term to apply to quantum entities. The concept of electrons is not a simply convenient manner of speaking. The necessity of the predicate 'veiled' to qualify that reality reminds us that it must be encountered on its own terms and in accordance with its Heisenbergian uncertainty. In other words, there is no universal epistemology. We can only know the quantum world in terms respectful of its veiling, and it would be epistemically disastrous to try to insist on a Newtonian clarity. The other comment relates to the ground on which the reality of quantum entities is to be defended, even including the reality of confined entities such as quarks and gluons that we believe will never be observable individually. The basis for belief in these unseen realities lies in the way in which that belief makes sense of great swathes of accessible physical phenomena - in the case of quarks, the structure of the hadronic spectrum and the results of deep inelastic scattering. In the mind of the physicist it is resulting deep intelligibility that is the ground for ontological faith. I think that this is a lesson with an applicability wider than to physical science alone.

(5) *A Universe of Open Process*. The twentieth century saw the death of a merely mechanical view of the world. Its demise came about through the discovery of widespread intrinsic unpredictabilities present in physical process, first at the subatomic level of quantum theory, and then at the everyday

level of those exquisitely sensitive systems that have been given the actually ill-chosen name of 'chaotic' In fact, chaos theory involves a subtle interplay between order and disorder, future behaviour being unpredictable but not totally haphazard.

All scientists would agree that these are highly significant and surprising discoveries, but the matter becomes more contentious when we go on to discuss what they might actually imply for the process of the world. Unpredictability is an epistemological property and there is no inevitable connection between epistemology and ontology. What connection we make is a matter of metaphysical choice and philosophical contention. In particular, questions of the nature of causality are always ultimately metaphysical in character, as the unresolved dispute between Bohm and Bohr about whether quantum theory should be considered deterministic or indeterministic in its fundamental character makes only too clear. Different people will adopt different strategies. As a scientist, my instinct is to adopt a realist stance, that is to say to believe that what we know is a reliable guide to what is the case. I have encapsulated this metaphysical strategy in a slogan I coined and that I rather like: 'Epistemology models Ontology'. After all, why take all the trouble involved in doing science if one did not believe that thereby we are learning what the physical world is actually like?

If you take this realist view, then unpredictabilities will not be seen as unfortunate epistemological deficits but rather as signs of an actual ontological openness to the future. The vast majority of quantum physicists take this view when they side with Bohr against Bohm and see the uncertainty principle as a principle of indeterminacy and not merely of ignorance. I have proposed that we should do the same with chaos theory, regarding the deterministic Newtonian equations from which the discussion began as no more than emergent downward approximations to a more subtle and more supple physical reality. By that claim, of course, I do not mean that the future becomes some random lottery, but that the causes that bring it about will be more than simply the exchanges of energy between constituents that a conventional science describes. What then might be nature of such additional causal principles ? First, the unisolatable character of chaotic systems implies that

this new form of causality will be holistic, referring to the behaviour of the system as a whole and not simply to its separate parts. I also suggest that these principles will be concerned not with energy but with what one might call information, that is the generation of patterns of behaviour. The unpredictable future possibilities of a chaotic system differ from each other in precisely this way; they correspond essentially to the same energy but to different patterns in which the energy flows. This leads me to the sixth property of the universe that is of ontological interest and promise.

(6) *An Information-generating Universe.* I believe that we are on the threshold of very interesting new developments in basic scientific understanding. Through computer simulation and some other techniques, we are just beginning to learn something about the behaviour of genuinely complex systems. It turns out that they display quite astonishing propensities to the spontaneous generation of patterns of large scale order. A very striking example of this has been given by Stuart Kauffman in his computerised investigations into the behaviour of Boolean nets of connectivity 2. The details are not important for our present purpose, but the results are extremely intriguing. If the net contains 10,000 elements, there are about 103000 states in which it might be found. However, in certain well-defined circumstances, such a net started of in a random configuration will settle down to cycling through about only a 100 different states.

That represents the spontaneous generation of an altogether astonishing degree of order.

At present these matters are not well understood, but I believe that the science of the twenty-first century will be characterised by making pattern, and the information that specifies that pattern, a fundamental category in scientific vocabulary, alongside the traditional concepts of matter and energy. We might then expect to be able to combine this new emphasis on patterned behaviour with the causal openness proposed in the last section, thereby adding to the portfolio of our causal imagination the concept of 'active information' a dynamical pattern-forming propensity that operates in an holistic way on totalities rather than separably on constituents. Here we may see a *glimmer* - I say no more than that - of how it might be that we enact our chosen patterns of behaviour as intentional agents. Even at this conjectural stage of discussion the proposal obviously requires more consideration than I can give it now, but it is something that I have tried to lay out in somewhat more detail elsewhere, not only in

relation to human agency but also in relation to the theological issue of the action of divine providence.

(6) *A Universe of Eventual Futility*. On the largest possible scale, the history of the universe is a continuing contest between two opposing principles: the explosive force of the initial big bang, driving matter apart, and the contractive force of gravity, pulling matter together. They are very evenly matched and, while cosmologists currently favour the possibility that expansion will predominate, it would be prudent for thinking about the significance of the long-term cosmic future to take into account either possibility. If expansion prevails, the galaxies will continue to fly apart for ever, slowly cooling and decaying until the world ends in a dying whimper. If, on the other hand, gravity prevails, the present expansion will one day be halted and reversed and the world will end in a bang, as the universe collapses back into the melting pot of the big crunch. Either way, the cosmos is condemned to eventual futility. It is as certain as can be that carbon-based life will everywhere prove to have been a transient episode in its history.

These reliable but bleak prognostications do not support any notion of long-term evolutionary optimism, of a total and lasting fulfillment to be found within the unfolding of present cosmic process alone. For theology they raise the issue of whether this eventual futility is compatible with the claim that the universe is a creation, the expression of the benevolent will of its Creator.

On this occasion let me content myself with saying that I recognise that the issue is one of great importance, but I do not think that the knowledge of the universe's death on a time scale of many tens of billions of years raises any greater theological difficulties than does the even more certain knowledge of our own deaths on timescales of tens of years. In fact, if there is hope, either for the universe or for us, it can only lie in the eternal faithfulness of God. There can be theological hope of a kind that is indiscernible from purely naturalistic considerations.

What is at stake here is the fundamental metaphysical issue of whether the universe is a cosmos or a chaos. Does the universe make total sense, both now and always, or is its history ultimately 'a tale told by an idiot, full of sound and fury, signifying nothing' ? The distinguished theoretical physicist

and staunch atheist, Steven Weinberg, surveying the scene from his naturalistic point of view concluded, in the light of eventual cosmic futility, that the more he understood the universe, the more it seemed pointless to him. He could only face it with a kind of heroic defiance. There is a certain nobility in that bleak point of view, but I do not believe that we are driven to embrace it. Yet if we are to be able with intellectual integrity to hold to a more hopeful view, I think this will require the kind of developed theistic system of belief that Christian theology provides. That is the kind of metaphysical belief that is necessary if we are to be able to recognise that our world is indeed a cosmos after all. But to pursue that matter would take me far beyond what is appropriate in a Conference focusing on physical science, and so I will conclude at this point.