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Explanations in Science and Beyond

The nature and scope of explanation are central to our understanding of the significance of science, and are also important in providing intellectual reasons for belief in God. However issues of complexity versus simplicity in explanations have been raised in this connection – in particular by Richard Dawkins and others when considering the organised complexity of biological systems. To clarify these matters, we examine the ways in which explanations and proofs operate in mathematics and in science. In particular, distinctions are explored between proximate and ultimate explanations, and between formal and factual aspects of explanations. Simplicity is in fact not of primary importance, because what is actually sought is the correct explanation. It is argued that science cannot provide a truly ultimate explanation for the universe but that God is the appropriate recourse here. God's complexity need not be greater than that of the universe, but is hard to assess and not very relevant because God is not a scientific explanation.

Keywords: explanation, science, physics, mathematics, God, complexity, simplicity, proof, paradigm

Introduction

As human beings we have a strong desire to obtain explanations for what is around us. The types of explanation that satisfy us can vary; they reflect the nature of the culture in which we find ourselves, and different explanations for the same facts will often coexist, because they answer different kinds of question and provide different kinds of understanding. Commonly, though, we seek to understand the existence and nature of something by explaining what has caused it to happen or what in some sense underlies it at a deeper level. In science, the aim typically is to account for a physical object in terms of what it is made of, and by showing that its behaviour is a consequence of natural laws.[1] Other types of explanation must be sought if we wish to consider questions that science chooses not to address, such as those of purpose and meaning.

It is useful to distinguish between proximate and ultimate explanations in science. The proximate, or immediate, explanation is the set of circumstances that form the direct reason for what we observe. For example, the pond in the garden froze because it was a cloudless winter night and heat radiated away,

1 A recent overview on the function of scientific explanation can be found in Lipton, P., in Cornwell, J. (ed.) *Explanations – Styles of Explanation in Science*, Oxford: OUP (2004).

lowering the temperature of the pond. But we may not be content with this. These circumstances surely demand an explanation in turn, which we will seek in terms of the Earth's weather patterns. We may wish to go still further, and try to explain the latter as a consequence of the history of the Earth, or even of the solar system and the universe as a whole. The laws of physics in their respective ways underlie all the above. An ultimate explanation would in principle be one beyond which we cannot go, but what is taken as ultimate in practice has its arbitrary side, depending upon the investigators' interests. For everyday weather forecasting, we are probably happy to take as a basis the reasonably well understood physical behaviour of the Earth's atmosphere, as our planet goes round the sun. This does not amount to a true 'ultimate explanation', but will suffice for the purposes of discussing meteorology.

Should an explanation be simple? If we are confident of our understanding of a scientific situation, then the explanation we obtain will be accepted even if it is complex. Correctness clearly takes precedence over simplicity. Controversy is apt to arise, however, in situations where hypothetical explanations are offered in the absence of experimental proof. The true explanation for a given atmospheric or biological phenomenon may not be known, and in such cases the complexity of a proposed explanation becomes a discussable issue. Aesthetic reasons apart, a simple hypothesis seems to promise better understanding. But we will argue that simplicity is a dubious principle to apply dogmatically in a scientific context and should become a side issue in the end. Our goal is the best *correct* explanation, however complex that may be.

Explanations and proofs in mathematics

The subject of mathematics provides a helpful testing ground for considering these questions. The standard practice in mathematics is to start with a set of basic statements, known as axioms, accompanied by some logical rules to allow us to deduce further statements. On this basis, general results known as theorems are derived. For example, the well-known Pythagoras' theorem states that in a right-angled triangle, the sum of the squares of the two shortest sides equals the square of the longest side. This fact was widely known in the ancient world and many different types of proof for it have been given over the centuries. Around 300 BC Euclid gave the first recorded proof of the theorem, using a small, well-defined set of axioms about the properties of straight lines and other basic aspects of geometry. It is not the simplest proof available, but it has historical importance as the first we know of, and in the formal manner of its presentation.

The essence of a proof lies in the fact that it provides full assurance of the truth of the theorem in all conceivable cases. Prior to Euclid's work, many examples had been known of sets of integer numbers satisfying Pythagoras' theorem. The best known of these is that the squares of the numbers three and four add up to that of the number five, and a triangle whose sides are three, four and five units is right angled. On the basis of such examples it is quite easy to imagine that Pythagoras' theorem is universally true, but Euclid's proof converts conjecture into certainty, provided that we are prepared to accept his axioms and the use of ordinary logic as the rules of deduction. All this, in normal circumstances, appears to be common sense and difficult to doubt.

As an alternative viewpoint, we can regard the axiomatic proof as giving an *explanation* for the theorem. Explanations and proofs work in opposite directions, the explanation answering the question 'why' with 'because', while the proof says 'therefore'. From the point of view of a proof, we start with axioms and build up, combining different proved facts until the theorem of interest is reached. From the point of view of an explanation, we start with a statement of the theorem as a believed or proposed truth, and the proof then comprises the explanation as to *why* it is true. Such an explanation will apply both to the general theorem and to any given instance of it, for example, why the numerical relationship holds for a particular right-angled triangle. In the course of a proof, there may be intermediate proved results which lead to the theorem and can be considered as a 'proximate explanation' for it. The axioms and deduction rules, if we accept their validity, constitute the 'ultimate explanation'.

It is in fact a mistake to assume that mathematicians always work by building proofs up from first principles, ending up with theorems whose existence was unsuspected before the logic was followed to its conclusion. This can happen, but it is probably exceptional, because a virtually unlimited number of mathematical arguments may be constructible from a given set of axioms, and most of them will lead like random paths through a forest, to nowhere very interesting. A mathematician will prefer to have at least a glimmering of the kind of theorem that may be provable, and it can happen that a theorem is asserted as a 'provisionally believed conjecture' long before a proof is finally found.[2] In some such cases, we still await the proof.

Some famous examples of this can be quoted. The mathematician Fermat proposed what is known as his Last Theorem in 1637: it states that if we have three positive integers a, b and c, and each is raised to the power n, then the equation $a^n + b^n = c^n$ has no solutions when n is greater than two. So two squares can add up to another square, but two cubes cannot add up to another cube, nor can this occur for any other higher power than a square. Fermat's own claimed proof was never revealed, and his theorem retained the status of a conjecture, proved for special cases and generally believed to be true, until Andrew Wiles finally published a full proof in 1994.[3] One can view a proof as

2 For how mathematics can sometimes resemble an 'experimental science', in which conjectures are formed and tested empirically, see Echeverria, J. 'Observations, problems and conjectures in number theory – the history of the Prime Number Theorem', and references, in Echeverria, J., Ibarra, A. & Mormann, T. (eds.) *The Space of Mathematics*, Berlin: de Gruyter (1992).

3 For an accessible account, see Singh, S. *Fermat's Last Theorem*, London: Fourth Estate (2002).

an explanation for a believed fact, or the fact as emerging out of the axioms, but the first point of view here is historically the more accurate. Another celebrated conjecture that found a proof only after a long period of being widely believed was the so-called 'four-colour theorem', which states that any map on a flat or spherical surface can be painted using no more than four different colours so that no two adjacent regions have the same colour. First proposed in 1852 by Francis Guthrie, a law student at the time, this took less long for its solution than Fermat's theorem; a proof was eventually given in 1976 by Kenneth Apel and Wolfgang Haken.[4]

We will have more to say later about these celebrated theorems, but in their cases it was certainly a commonly believed 'fact' that sought an explanation, in the form of a proof that would make it certain and universal starting from standard axioms, rather than a theorem that emerged unforeseen from a deductive argument.

Modes of explanation in science

There are three important ways in which science attempts to answer the question 'why?' which we can term historical, compositional (or 'analytic') and in terms of laws ('nomological').[5] They can be combined. Historical explanations account for a specific set of phenomena in terms of previous causes, these in terms of earlier causes, and so on. Such explanations apply, in particular, to evolutionary accounts of how living species have developed. Any train of causes and effects can be in principle extended, should we wish, back to the cosmic Big Bang.

A compositional explanation accounts for the properties of a compound system in terms of its constituent parts and their arrangement. Thus, a crystal is composed of atoms in a certain pattern, atoms are made up of elementary particles, and so on. A nomological explanation accounts for patterns of observed behaviour in terms of laws of nature, and the latter may have an explanation in terms of more fundamental or more general laws and principles. A compositional explanation may reach a stopping point, at which stage we will concentrate more on the laws of nature: for example, the laws that make possible the elementary particles. A historical explanation relies on laws of nature to govern the causal processes and may often be *statistical*, dealing with frequency

4 Appel, K., Haken, W. & Koch, J. 'Solution of the Four Color Map Problem', *Scientific American* (Oct. 1977) 237, no. 4, 108-121; Wilson, R. *Four Colours Suffice*, London: Penguin Books (2002).
5 Many detailed discussions of this subject may be found in the philosophical literature. The most standard modern approach, largely followed here, is known as the deductive-nomological (DN) model and was formulated by Carl Hempel. See Hempel, C.G. *Philosophy of Natural Science*, New York: Prentice-Hall (1965), p.49ff. and Hempel, C.G. *Aspects of Scientific Explanation*, New York: Free Press (1965), p.335ff.

probabilities for laws to have certain consequences.[6] In physics, in contrast to biology and cosmology, the explanations are mainly compositional and nomological.

The other sciences are often held to reduce to physics because of the generality of the explanations physics provides. Especially in biological systems, different types of complementary cause may often be ascribed to a given situation: functional, genetic and even teleological.[7] The question then is how ultimate these various explanations may be. *Physicalism* is the hypothesis that only physical explanations are ultimate.

I will use the term 'formal' to denote all aspects of explanations that refer to 'forms' in a very general sense: laws, causes, patterns, concepts, theories and so on. But an explanation may well also depend upon physical facts. A scientific explanation must have a starting point, and this may consist of basic concepts that are believed, or a set of accepted physical facts, or both. The initial conditions of a historical explanation are likely to be physical facts, and likewise the elemental entities of a compositional explanation. Both the formal aspects and the factual aspects of an explanation are important.

The status of laws of nature

Before going further, we must say more about the role of laws of nature as explanatory principles. Such a role is contested by those who take an empiricist standpoint, in which a law of nature is regarded as a mere mathematical description, or model, of a body of observational data. This would have serious implications if it were true, since a description of a set of data cannot at the same time be an explanation for it: 'what' is not the same as 'why'! If this is all that laws of nature are, they cannot have an explanatory function. This point needs clarification before we can proceed.[8]

Some observed facts have human descriptions that are undeniably no more than this. Thus, the stars of the constellation Leo form the shape of a lion, but this is merely our description of their pattern. The human nomenclature

6 See Hempel, C.G. *op.cit.*, (5), p.376ff. Statistical laws can be included in the DN model (Railton, P. *Philosophy of Science*, 45, (1978), p.206; reprinted in Pitt, J. *Theories of Explanation*, Oxford: OUP (1988). For a more recent review, see Salmon, W. *Causality and Explanation*, Oxford: OUP (1998), p.302ff. While disagreement exists among philosophers on topics such as epistemology and causality in science (*ibid.*, p. 320ff.) our discussion here is not greatly affected by this. But it is important to note that historical explanations require causation to operate in some sense, and not mere deducibility of one fact from another.

7 See the articles by Rose, S. and Hanke, D. in Cornwell, J. *op. cit.*, (1).

8 For a more extensive discussion of the issues in this section, see the article by Weinberg, S. in Cornwell, J. *op.cit.*, (1). Weinberg emphasises that theories themselves can be *explained* by deeper theories, something that is entirely dubious if they are mere descriptions. For further debate see Churchland, P.M. & Hooker, C.A. (eds.) *Images of Science, Essays on Realism and Empiricism* Chicago IL: Univ. of Chicago (1985) and in particular the article by Glymour, C.

implies no *physical* necessity for the pattern and provides no explanation for it. The next step up is when natural regularities are found which suggest a general law, even though no explanation is available. The astronomer Kepler put forward three 'laws' of planetary motion, stating that the planets move in elliptical orbits, and certain relationships exist between their speed of revolution and distance from the sun. These 'laws' described well the behaviour of all the known planets, but at the time they were just an interesting empirical observation.

Newton's later Universal Law of Gravitation implies Kepler's laws as a mathematical consequence, and is therefore capable of providing an explanation for them. According to Newton's law, a force of attraction acts between any two physical objects, proportional to their masses and to the inverse square of their distance of separation. What gives logical priority status to such a law is its generality: from the universal we can deduce the particular. Different kinds of observable facts can be derived from it – for example, we can check Newton's law by measuring various types of orbits of comets, and even by making direct laboratory measurements of the force.[9] In contrast, no other types of phenomenon follow from Kepler's laws. One feature of a universal basic law, then, is its ability to give rise to, and hence explain, different kinds of phenomena; it does not describe just one set of data.

While Newton's law is indeed descriptive of the phenomena to which it is applied, its more profound significance concerns the status of law in nature. It really does appear as if mathematical patterns are built in a universal way into physics. The presence of law gives an explanation for the regularities observed in the particular instances, for without it there is no reason why things of the same type should all and always behave in the same way. In observing that they do so behave, we would otherwise face a very large number of remarkable coincidences. To repeat: either there is a reason why things of the same type always have the same properties and behaviour, or there is not. If there is, then such a reason amounts to a universal determining factor – what else could be meant? – and this is what we call a law of nature. On this basis, then, it is reasonable to take laws of nature as determinative agents and hence explanatory factors for what is observed in science. This implies a certain reality about them.

If 'laws of nature' were really no more than descriptions, then empirical facts alone have significance. Things do or do not happen – that is all. But this is not what we really believe; our common practice is to rely strongly on having determinative knowledge based on laws of nature.[10] We successfully base many of our human activities on regarding laws in this way. In what follows, therefore,

9 Small deviations from Newton's law arise due to Einstein's General Theory of Relativity, but this is not important for us here.
10 This whole area, of course, has been a matter of perpetual debate following the philosopher David Hume's original empiricist stance in his *Enquiry Concerning Human Understanding*.

we will continue to regard them as participating in explanations.

Levels of explanation in science

There are a number of similarities in the ways that proofs and explanations operate in science and in mathematics. In any given area of science, after some experimental facts become known, an explanation is sought with the hope of achieving a full theory that operates in the general style of a mathematical proof. A set of basic facts and principles, appropriate for the given scientific area, will play the role of axioms and deductive rules. In some branches of theoretical science, new theories can be constructed by choosing these axioms fairly freely – as in principle is the case in mathematics – though probably with a constraint that they be 'reasonable'. Experimental testing must be sought for any new set of theoretical ideas.

Even in a branch of science with its own local assumptions and methods, it is common, as we have said, to believe that everything may in principle be taken back to the subject matter of physics. But even if it were true that physics could provide a 'more ultimate' explanation, this may not be practicable or useful. If we are studying the behaviour of bears, the context will be one of animal species and their environment, with basic principles and understandings set out at this level, and we are unlikely to feel a need to delve back into quantum physics. Pragmatically, every field operates within a finite context that facilitates its work. To probe it all back to the Big Bang or quantum field theory is unnecessary and irrelevant, and very likely not even feasible. The chain of explanations is most likely to begin with an explanation for an experimental observation in terms of some proximate reasons for it. These will eventually be explained by the basic facts and principles conventionally employed in the field. The latter serve as a locally effective 'ultimate explanation' from which all the observed phenomena in the field should arise as a logical consequence, in analogy with an axiomatic proof in mathematics. However a deeper level of explanation can always be aimed for.

To illustrate these themes, consider how we might explain the existence of a rainbow. Certain factual aspects are important, namely a shower of rain and some sunshine. Then we can make use of the known behaviour of light rays as they pass through raindrops. The laws of optics, namely the laws of reflection and refraction, determine the behaviour of the sunlight, and these laws can be regarded as the ultimate formal explanation for the rainbow if we do not desire to go further. However we would nowadays tend to see them as an intermediate stage, needing explanation by something more basic, such as electromagnetic waves as given by Maxwell's equations. The explanation in terms of the laws of optics now has a proximate status, although remaining valid in its own right. At the time of Newton's original investigations of optics, however, it was not known whether light consisted of waves or radiated particles, but the known laws of reflection and refraction could be constructed on either basis. So, even when a deeper explanation is not available, we may still be able to understand the observed phenomena at the level of a proximate explanation that is 'provisionally ultimate'. It may be noted that the ideas at this level can well be simpler than those that explain them at the underlying level. Thus Maxwell's equations are *more* complex than the laws of optics. But they are far more general in their scope and application.

Ultimate explanations in science

Suppose we seek to take science back to a truly foundational ultimate explanation. We start with a branch of science of our choice, trace its contents back to laws and facts of everyday physics, and explain these in terms of atoms and molecules. Now we introduce quantum theory and take the explanation back a further step to elementary particles. From here we seek a deeper explanation either in terms of 'more elementary' particles or else we look for a more general theory that can account for all the elementary particles. Then we seek a theory that will give rise to the ideas of this theory. The question is, how can this process terminate if we still desire to remain within the domain of science? We will allow new laws, and different types of law, but we will still wish to see them as laws of physics. There would seem to be a limited number of options in this quest:

(1) The explanations go back for ever with no stopping point. We would not expect to be able to reconstruct such an infinite sequence, however, or even necessarily know that it exists.

(2) They stop at something for which there exists no further explanation, even though its truth is not logically compelled and might therefore have an explanation.

(3) They stop at something that is a logically necessary truth.

(4) Our own minds become incapable of understanding the nature of the explanations at some stage.[11]

(5) The explanation at a certain point is sufficiently different from the science of physics that we can no longer call it science or physics.

Here science differs from mathematics. A given area of mathematics has a clearly defined axiomatic starting point, which represents the 'ultimate explanation' for all of its contents. There is no need to demand deeper axioms from which the given set can be proved. We might decide to look for alternative axioms that are in some sense preferable, or we might engage in a philosophical discussion about the axioms, but there is no necessity for any of this. No further 'explanations' are due.

11 This theme has been explored by Colin McGinn in *Problems in Philosophy, the Limits of Enquiry*, Oxford: Blackwell (1993).

However, we are bound to conclude that science is not actually capable of providing a truly ultimate explanation for the phenomena we observe around us. Consider the cases listed above. If, as in (1), there is an infinite regress, then there exists no ultimate scientific explanation, in much the same way that there exists no largest integer. A possible line of escape could be that an infinite series of explanations might somehow be combined into a single explanatory concept. But in that case we would ask for an explanation for this concept. In the case (2), it might be that the stopping situation 'just happens' or, equivalently, just comprises random effects. If we were to try to find a further scientific explanation, we would not succeed. In the absence of logical necessity there would be no way to be sure when to stop, but in practice we stop at this point, or possibly even at the wrong point, before the science stops. But science has ceased to provide the goods, and this kind of stopping point does not comprise in a true sense an ultimate scientific explanation – merely the absence of one. It is the end of a road that might have led further: the unanswered question 'why' still exists and can be asked.

Possibility (3) is implausible, if our ways of thinking are to remain scientific, because it implies a final stage that has no logical possibility of being otherwise: for some reason, science is now forbidden to ask a further question 'why?' But such a situation is hard to imagine, since science seems always able to propose alternative possibilities, while logic in a scientific context always finds itself applied to something, for which we can therefore demand a reason, or else we can take issue with the nature of the logic. It does not seem that science is really able to terminate in this way.

While it is perfectly conceivable that we may fail in our search for further scientific explanations at some point, case (4) suggests a different situation. It refers not to the mere absence of a known scientific explanation, but to a situation where the very nature of the next explanation would be incomprehensible to us, whether or not we realised this. But science is a discipline that we employ in a humanly defined way, and if we lack the capacity to recognise something as science, then it is not science – whatever else it might be. The situation has radically diverged from what we call science. This leads into possibility (5), which takes the explanation explicitly out of science's hands. The ultimate explanation, if it exists, is not a scientific one.

Case (4), we repeat, does not refer to the possibility that beyond a certain point the physics may merely be unknown to us, as it would be in case (1). Physics deals with observable quantities whose behaviour is given by mathematical laws, and an explanation other than this is not physics. Thus multiverses are a scientifically problematic idea because of their possibly permanent unobservability,[12] but the relevant mathematical concepts still remain within our mental grasp. Our intuition is that our minds are capable of formulating

12 Bussey, P.J. *Science & Christian Belief* (2006) 18(2).

any necessary kind of mathematics. Within this scenario, then, 'physics' by its nature cannot be something qualitatively transcendent to our minds, even though its interpretation may be.[13] Whatever is transcendent to our minds lies outside the scope of what we would take or understand to be physics.

At some point, we can no doubt expect the relevant scientific experiments to become unfeasible. Even so, theorists will remain free to propose further hypothetical explanations. Such proposals cannot attain the status of hypothetical ultimate scientific explanations, however, because the discussion above will still apply to them.

Complexity, simplicity and probability

If an explanation is true, then its degree of complexity is irrelevant once it is simplified as far as possible. However, we might still wonder whether all true explanations are in the end simpler than the facts which they explain. Here again it is necessary to distinguish between proximate and ultimate (or provisionally ultimate) explanations. It is undeniable that the proximate explanation for a simple fact can be highly complex, even if the ultimate explanation is relatively simple.

Fermat's Last Theorem provides an excellent illustration. The proof that was discovered is long and subtle even though the theorem itself is understandable by any numerate person. The four-colour theorem for maps, our second example above, was proved by reducing the issue to some two thousand special cases, and the authors wrote a computer program to work its way through these. The complexity has since then been reduced a little, but an author of a later version of the proof remarked nevertheless that 'the entire argument occupies about 13,000 lines, and each line takes some thought to verify. Therefore, verifying all of this without a computer would require an amount of persistence and determination my coauthors and I do not possess.'[14] So a computer still had to do it. These complex proofs constitute proximate explanations for very simple mathematical statements, for which the ultimate explanation in turn lies in a simple set of basic mathematical axioms – but we cannot go straight from these to the final results. Proofs quite as complex as this are perhaps exceptional. However an interesting theorem does usually possess a quality of simplicity, and in mathematics it tends to be seen as particularly 'beautiful' when a simple result emerges as the outcome of a highly irreducibly complex line of argument!

Other things being equal, a simple set of axioms will be preferred to a com-

13 A good modern account of the different interpretations of quantum mechanics can be found in Baggott, J. *Beyond Measure*, Oxford: OUP (2004).
14 Thomas, R. 'An Update on the Four Color Theorem', *Notices of the American Mathematical Society* (1998) 45, 848-859.

plex set, but we may well find in practice that a set of mathematical axioms is not really overall any simpler than a given theorem that arises out of it. Euclid's set of geometrical axioms, even selecting only those relevant for Pythagoras' theorem, might well be considered to be slightly more complex than the statement of the theorem.[15] The axioms do have a good degree of simplicity, but they much more importantly have the quality of being 'basic' and of having wide application.

Simplicity in science can be misleading or just wrong. It was simple to attribute malaria to 'bad air', but the true and complex explanation is in terms of the life cycle of a parasite of a particular species of mosquito. At the end of the day, to demand simplicity in a given situation may or may not be appropriate – sometimes complexity is unavoidable. Within physics, simple phenomena with complex explanations include superconductivity and the spin-statistics theorem for quantum particles.[16] Most of the known basic laws may be considered fairly simple, but we still have to assemble the mathematical apparatus of quantum mechanics, field theory, quantum chromodynamics, General Relativity, and other ingredients. If this were all truly simple we would teach it to first year undergraduate students, but it is not, alas! There are continuing searches for a 'theory of everything'; such a theory again will probably be highly sophisticated, for otherwise we might expect to have had it long ago. Physicists certainly like simple proofs, as do mathematicians; sometimes these are available, sometimes not.

Some kinds of explanation can be too simple, and earn the epithet 'simplistic'. This is particularly the case in human situations; human beings are complex and we expect complexity in an account of their affairs. Two areas where this warning has especially been ignored are analytical and evolutionary theories of psychology. All that can be said briefly here is that Freud's reduction of human psychology to a very small number of general principles has received a crescendo of criticism over the years, while fierce controversy rages over the attempted psychological applications of evolutionary theory.[17] The main problem with such underspecified theories is to obtain precise, specific and falsifiable predictions from the broad principles. Regarding evolutionary psychology, Noam Chomsky has complained: 'In fact, just about anything you find, you can make up some story for it.'[18] This, we may say, is the converse of Occam's razor! Instead of too many well-defined explanatory elements, there are too small a number of ill-defined ones. Even if the proposals have some truth, the explanations they offer are incomplete, and experimental evidence cannot easily falsify them.

15 In fact, later mathematicians argued that Euclid should have included more axioms in his list.
16 The combined wave functions of particles with integer spins or half-integer spins are respectively symmetric or antisymmetric in the individual wave functions.
17 See Rose, H.& S.(eds.) *Alas Poor Darwin, Arguments against Evolutionary Psychology*, London: Jonathan Cape (2000).
18 Quoted by Horgan, J. in *The Undiscovered Mind*, London: Phoenix (2000), p.179.

Why then do we like simpler hypotheses? Some reasons are as follows. There is a fear that by making an explanation sufficiently complex one can explain anything.[19] Complex hypotheses may have more side effects that can prove false when tested – so they are riskier hypotheses, although the falsifiability is a good scientific feature. If the elements of a complex hypothesis all require precise specification, then this is like proposing a set of 'coincidences', something we are reluctant to do. Moreover, a complex hypothesis is likely to require more explaining at its own deeper level than a simple one. Conversely, if a simple hypothesis successfully explains a number of things, it pleasantly removes them from the category of 'coincidence'. This is indeed the compelling feature of realist laws of nature; a few laws explain a very great amount of data.

The above considerations are plausible in dealing with hypothetical proposals, but they are much less relevant when the true explanation is established, and we may wonder, given that proximate explanations may be complex, how are we to tell when the simplicity criterion is really needed. Simplicity, we conclude, should really just be a guideline.

A further issue is about the *probability* of a proposed explanation. When the latter is not firmly established, and so must be considered hypothetical, it would be good to assign to it some kind of 'quality'. This is often done in terms of a level of 'probability', which can take several forms.[20] Sometimes a statistical probability can be given; for example the police say there is a sixty percent probability for the hypothesis that the murderer was someone known to the victim, because the latter has been found to be true in this fraction of similar cases in the past. If the hypothesis is complex, it may seem to require many factual or conceptual 'coincidences'. By assigning probabilities to these, we can then perhaps attach a numerical probability to the hypothesis as a whole.

Statistical probabilities will not work in one-of-a-kind situations, such as the existence of our universe or with many new scientific ideas. Here we need to consider various a priori factors, and the probability assigned to a proposed explanation will be to some extent subjective. Probability now implies believability, bearing in mind that if we have several intrinsically believable hypotheses, each will have a reduced 'probability'. Simplicity is attractive, and can increase believability by giving us less to believe, but another factor is the consonance of the hypothesis with other things we believe to be true. There is no fixed formula here; much depends on the individual's own prior viewpoint. An important thing is to beware of assigning misplaced 'statistical' probabilities.

What if the choice turns out to be between an explanation and no explanation? An example of this is to be found in quantum physics; if a particle is

19 Underspecified hypotheses have this same problem, as we have seen. Darwinian explanations of all kinds are also frequently accused of it. Of course, they can turn out to be correct anyway.
20 Swinburne, R. *Epistemic Justification*, Oxford: OUP (2001).

exposed to a piece of apparatus and a number of different outcomes could occur, then the occurrence of any one of them is normally believed to be random, subject to a probability distribution given by theory. Within this context, there is no precise explanation for the 'quantum event' that occurs in a given instance. This interpretational position is found unsatisfactory by a minority of physicists, who believe that all things must be physically determined. Theories of 'hidden variables' have been proposed, in which an unobserved physical quantity behaves in a defined way that determines how a given quantum event will occur.[21] The hidden variable law, if we accept it, is therefore the explanation of the quantum event, despite a lack of experimental confirmation for the existence of the hidden variables, and the fact that such theories tend to be somewhat complex. In practice it is the unconfirmability, more than the complexity, that would lead most physicists to reject such theories, but for those who have a strong philosophical commitment to determinism such objections have no compelling power. The primary question relates to whether an explanation is really needed, and so in this way a priori understanding again takes precedence over complexity arguments.

Changes of paradigm at different levels

Richard Dawkins has argued that as an explanation for the universe, or at least for the development of advanced life, the idea of God must be very complex and is therefore unhelpful. He writes: 'However statistically improbable the entity you seek to explain by invoking a designer, the designer has got to be at least as improbable',[22] where he takes complexity to be equated with improbability.[23] But can one really talk 'statistically' about God? A different *type* of probability[24] seems required in this case; Dawkins is not very precise at this point.[25] His suggestion has generated much controversy, including in the pages of this journal.[26] As we have seen, however, it is no easy matter to judge when complexity is problematic in an explanation; indeed, an equally valid complaint might be that the idea of God is too simple. But neither, we shall

21 For a general account, with more detailed references, see Baggott, J. *op. cit.*, (13), ch. 11.
22 Dawkins, R. *The God Delusion*, New York: Mariner Books (2008), p.138.
23 Dawkins, R. *Climbing Mount Improbable*, New York: W.W.Norton (1996), p.77.
Human designers exist of course. They are certainly complex. They have presumably evolved, but it is not at all clear a priori whether the complexity produced by this means has a necessary connection with the complexity associated with design ability. One of these is biological and the other mental, so that two different types of complexity may end up being confused with each other. We need more understanding of the nature of the mind to answer this issue.
24 cf. Swinburne, R. *op. cit.*, (20).
25 However Dawkins' argument would certainly hold against multiverses. To account for a statistically improbable universe (ours) you must postulate a very complex ensemble of multiverses!
26 See Richmond, P. *Science & Christian Belief* (2007) 19(2), 99-116. Richmond gives an interesting and well-informed account of many aspects of theological explanations, but is in my view a little over critical of some of the arguments raised against Dawkins' position, and places too much stress on simplicity.

argue, is really relevant here and Dawkins' argument is anyway unsound.

The theologian Del Ratzsch has proposed a story to illustrate a legitimate need for complexity in certain explanations.[27] He considers the case if 'a perfect ten-meter cube of pure titanium were discovered on Mars. Most people would think that the cube was produced by aliens and would regard the cube as virtual proof that aliens existed.'[28] This would be despite our total lack of knowledge about the aliens; the proximate explanation in terms of aliens is simply the only real one on offer. As an explanation it appears both complex and incomplete, but the cube cannot be accounted for on the basis of simple natural laws and processes, and we would really like an explanation. We just have to assume that the aliens somehow resemble human designers. A more basic and 'ultimate' explanation might require knowledge of the aliens' origins and purposes, which are hidden from us – but none of this is immediately needed for explaining the presence of the artefact. We will surely be satisfied that we have a proximate understanding of how the titanium cube most probably came to be on the planet.

Let me enlarge this message with a more down-to-earth tale. You are touring the grounds of a stately home and you come upon a maze. After spending some time exploring its complex, elegant and intriguing construction you emerge full of admiration, and seeing a gardener in the vicinity you approach him and ask, 'Can you tell me about the origins of this maze?' 'Why, yes,' replies the gardener. 'That maze there was designed a hundred years ago by the tenth earl!' But at this point you suddenly become a little impatient. 'Come now my man,' you say rather rudely, 'that's no proper answer at all! Because, in that case, just tell me this. *Who designed the tenth earl?*'

The issue here is not that the gardener should have given an evolutionary history of the world culminating with the genetic constitution of the tenth earl. Surely that would be quite beside the point, and probably inconclusive as well. My argument is that at certain stages in taking explanations back step by step, the nature of the useful questions and of their answers is likely to change, possibly quite radically, and it is naive to insist on asking the same type of question for ever. Our *understanding* has to change. The second question in the tale above, therefore, was simply misconceived. This is the chief fallacy of those who insist on asking 'scientific' questions about God.

Ultimate explanations may well turn out to be different in kind from proximate explanations, but in the absence of ultimate understanding we will have

27 Ratzsch, D. *Nature, Design and Science, The Status of Design in Natural Science* Albany NY: State University of New York Press (2001), p.135.
28 This is an example of what Hempel calls a 'self-evidencing' explanation: the explanation that is advanced itself provides evidence for the proposed source of the phenomenon (Hempel, C. *op. cit.*, (5), p.372ff.). The theological question is then to what extent God, as an explanation for the universe, is self-evidencing in Hempel's sense.

to be content with the latter. Science strives to press its explanations back, step by step, but even within science there is from time to time the need for a new paradigm. To take biology back we must move to chemistry; to take chemistry back we move to physics. To understand physics at the atomic scale, we must move to a quantum approach. The methods and concepts of classical physics, employed since the days of Newton, will no longer do. It is natural to try to take a successful paradigm back as far as it will go, but dogmatism in this area has proved wrong in the past.

The role of factual complexity in evolution

It is of particular interest to us to try to explain the formation of the complex organised structures known as living creatures, and especially of ourselves. These biological structures certainly give an appearance of design, and Darwin's achievement was to point out that over sufficiently long periods of time, simple organised reproducing structures might evolve naturally into complex ones, provided that random mutations can take place and suitable developmental pathways are available.

When considering organised structures, the distinction between the formal and factual aspects of explanations is particularly important since it gives rise to the difference between design explanations and statistical explanations. In the case of a design, a conceptual pattern is imposed on a situation by an external agent, and we may even consider laws of nature as patterns imposed on physics, without at this point debating their possible origins. A different kind of account can be through a 'factual explanation'. This may be along the lines that if a large and complex set of natural entities exists or is formed as a physical fact, then one or more of them from a statistical point of view may be expected to resemble the particular item that requires to be explained.[29]

Human designers exist, and so there is no reason to reject design arguments out of hand. The design explanation for the maze is indeed the correct one, even though it demands quite a complex set of concepts within the mind of the designer earl. The alternative would be to postulate the existence of many millions of stately homes, all with bushes and hedges in their gardens, growing by chance, of which at least one set would very likely have the arrangement of a maze. This is the one we choose to visit. The formal component to this fact-dominated explanation is somewhat simple – bushes, hedges and undirected growth, but the many cases necessary would imply an enormous quantity of physical complexity, if the required result is to be obtained, and of course this particular complex set of physical facts is not found to exist in practice.

The random element in statistical situations is essential to provide the com-

29 In cosmological physics, this question underlies the current disagreement on 'Theory of Everything or multiverses'. However, we will not pursue this topic further here.

plexity that generates the observed result. If the bushes and hedges were to grow according to a fixed natural pattern, it would be very surprising if that pattern were to produce a well constructed maze. Complexity can be specified mathematically.[30] It can be quantified as the size of a computer program that will generate a description of a given system, and although this in practice would vary with the computer, we can imagine the size of the shortest program that can be written for an idealised computer. A pattern contains a relatively low complexity since only a modest amount of data is needed to specify an algorithm for the pattern, and its parameters. A collection of random numerical quantities, on the other hand, has maximal complexity since each member must be specified individually. This maximises the number of bits of information needed to describe the system, and thus by definition its complexity. If the physical system is very large, a pattern still requires only a modest quantity of data, but a set of random numbers requires a number of bits in proportion to its size. Hence, the larger the physical system, the more advantageous it is from the point of view of low mathematical complexity to have a design or pattern, rather than a random numerical specification.

In the case of Darwinian evolution of advanced life forms, the concepts of genes, mutations and natural selection are perhaps fairly simple. But to generate a highly developed species, these formal elements must be embedded in an extremely large quantity of factual complexity, and this constitutes an essential part of the explanatory story. The explanation for our species must involve a suitable planet, the formation of a genetic reproduction mechanism and much complex biochemistry. But in addition, huge numbers of random mutations of genes must have occurred over long periods of time.[31] Lacking their own further explanation, these random physical facts are every bit as 'ultimate' as the other elements. Randomness, it must be appreciated, is not a formal concept like a law or pattern, but rather the *absence* of such. The individual instances must now all be specified individually. All in all there is no free lunch in this exercise. The complexity that gives rise to the complex result is supplied by means of a large set of numerical physical facts, and not just by formal quantities such as physical laws.

As a part of the account of our presence on earth, we accept the historical existence of this set of physical facts. But to ask about an ultimate explanation for the physical-biological system as a whole – or indeed for the entire universe – is this then really so unreasonable? Logically speaking, such an explanation might or might not be God as traditionally understood. But if in the story of life on Earth we are prepared to swallow the camel of exceedingly high physical complexity, then to seek to strain out the possibility of a Deity, even a fairly

30 This approach is based on G.J.Chaitin's formulation of complexity. For an overview, see Chaitin, G.J. *Scientific American*, (March 2006), 74-81.
31 As atomic-level processes, mutations are likely to have a strong quantum element to their randomness.

complex Deity, seems rather fussy. It is more than a little arbitrary to take happily on board a truly vast set of random events possessing no explanation, and then to complain about other people's explanations being too complex.[32]

It might be argued that God still needs to supply the values of all the random numbers. In reply we may suggest that God's activity could well include 'creative enabling', such that the random events are able to occur within nature without being designed individually. Since the physicalist alternative is to suppose that these random events occur in an *intrinsically* undetermined way, it can hardly really be insisted that God is obliged to specify of each one of them. We suppose that in God's mind, the concepts of physics and of natural selection are known to be adequate to generate the form of our universe, leading to ourselves. God provides an explanation for the system as a whole, therefore, *without* needing to contain the full degree of complexity contained within it. A purely physical account of our coming into existence must include all the random quantities that comprise an essential part of the process, a huge collection. God, on the other hand, needs to possess just the concepts and the originating creative power, delegating the random number generation to the created universe.

In summary, then, a quantifiable amount of complexity exists in the explanation for living creatures such as populate our planet. It occurs in formal structures, namely physical laws, together with a vast set of random numbers. Theism can attribute the laws to the Mind of God while regarding the random numbers as physical accidentals, a complex collection indeed but not a part of God. Physicalism cannot make this kind of distinction, since all is physical. God can therefore be simpler than the physical description of the universe, when the random numbers are properly taken into account.

God as explanation

Given our large and complex universe, organised by a set of sophisticated physical laws, a standard explanation is to suggest that it is the creation of God. Two separate issues are present which should not be confused: one is the question of simplicity and the other is that of how explanations regress. The former we have just discussed. With regard to the latter, we have noted that dealing with a train of possible scientific explanations may always have problems. If a point of 'no further scientific explanation' exists, then to go further something non-scientific is needed. If the set of explanations regresses for ever – a situa-

32 The common way to dispose of this-worldly design arguments, however, is in the end to dispose of design, even at the human level, by making the physicalist assumptions that all is ultimately explained by laws of nature (and randomness), that these do not contain design, and that conscious mentality is to be taken as a part of physics and so does not really contain design either. All these assumptions are highly contentious. I have argued against them in Bussey, P.J. *Science & Christian Belief* (2004) 16(2). Is the Big Bang really able to explain the Mona Lisa?

tion we probably cannot know about – then an ultimate explanation would again need to be of a transcendent kind, again non-scientific. Perhaps the scientific explanations themselves undergo a radical transformation. But if there is an ultimate explanation we must look outside science for it, and a different paradigm is to be expected.

Various non-physical transcendent explanations could perhaps be proposed for the universe. It is beyond the scope of this article to go into these questions, or to attempt to persuade the reader from first principles that the Christian concept of God is better than other possible explanatory transcendents. However the issue of God's supposed simplicity or complexity can still be discussed.

Here it is important to be aware that theists postulate God as both the proximate explanation and also the ultimate explanation for the physical universe. God is moreover traditionally proposed as being in some sense infinite, which might imply complexity although this is a matter of debate.[33] We have already argued that God can be simper than the universe, but in any case there is no absolute need for God to be simple. Human designers can have complex thoughts, and we have already accepted the existence of complex proximate explanations within science and mathematics, so why should a universe not arise out of quite complex thoughts in the Mind of God? They will provide a reason and specification for the universe at a more basic level than it, thereby comprising its proximate explanation. Such thoughts may very possibly have a simpler ultimate explanation, arising out of deeper thoughts within the Mind of God.[34] The latter, from our own point of view, could have some analogy to simple mathematical axioms that are able to generate complex but rich and elegant theorems. But here we are surely out of our depth, not knowing the appropriate questions to ask.[35]

Now, it might seem that theism is just as challenged as science when it comes to ultimate explanations, since we are in no position to understand how the latter really operate within the Deity. But the explanations are at least now being subsumed into something that we, acknowledging our human limitations, may reasonably accept as transcendent to ourselves. The mode of God's ultimacy is unlikely to be open to us; we do not have good cause to expect to know the answers here. Simplicity can be a valid criterion in comparing alternative scientific hypotheses, but it loses importance when the correct explana-

33 R. Swinburne has however argued the opposite in *The Existence of God*, Oxford: OU P (2004), where he proposes that finiteness is more complex, since it implies limitations that require information to specify.
34 We escape from the regress 'Who designed the designer?' by removing the demand for another *agent* and rephrasing the question as 'What designed the design?' which may be more tractable since demands for more designs may be easier to fulfil within the same agent.
35 It is for this reason that I have not stressed the argument that God is a 'necessary being'. Indeed He may be, but a necessity in terms comprehensible to us will tend to indicate some kind of logic existing prior to God that makes Him necessary. The logic itself, therefore, needs to be built into God's Being, and we are unlikely to understand its real nature.

tion is found, and becomes very hard to define if we are considering a transcendental explanation. On the other hand, to call a complete absence of final explanation 'simple' seems to be cheating. If an explanation is being sought that is 'ultimate' in any genuine sense, then science in any case cannot give it. With God our minds are given reason to know their limits, and the scientific quest turns into something different.

God should not be regarded as a 'scientific' explanation. For an explanation to be scientific, we would expect to test its consequences by controlled experiments, and although it is a common experience that faith in God does make a positive difference to human lives, there seems to be no laboratory experiment that would decide the facticity of the articles of faith. Neither can we make verifiable predictions about other universes that God might or might not have created. Our confirmatory information about God comes from trusted revelatory sources and from human personal experience, neither of which would be convincing to a scientific sceptic. The question quickly becomes whether all explanations should be scientific ones, itself a metaphysical question of a fundamental kind and one which is beyond the competence of science itself to answer. Science, it may be protested, provides *full* explanations, unlike theology! But in the end it does not, because it tends to deny questions it is not equipped to answer, and cannot provide a truly ultimate explanation. Science is a human activity, and we are finite. We have to live with some kind of ignorance or mystery.

Conclusions

In this article I have followed the standard line of supposing that a set of observational facts normally requires a reason or explanation. This may comprise an immediate or proximate explanation, and a train of more 'ultimate' explanations stopping at whatever point is attainable or scientifically convenient. But science is incapable of furnishing a truly ultimate explanation for the facts around us and for the universe as a whole, and to believe that it can would be a delusion, to employ a fashionable word. As regards simplicity and complexity in scientific explanations, either can be present at any stage; what matters is whether a proposed explanation is *correct*. Also, at various points changes in the explanatory paradigm are to be expected, even within science. To understand God to be a possible explanation for the universe, we are taking the explanation back a final stage, with another change of paradigm. This is indeed a very serious paradigm change, one that prevents us from using scientific methodology from now on, and in particular prevents the use of concepts such as complexity and simplicity in a well-defined way. But it does permit a pointer to be provided towards an ultimate reason for our universe, even though the details will be surely beyond our own comprehension.

Personally I have deep hesitations about any kind of human intellectualising about God's inner nature, even though a few ideas may need to be aired occasionally, 'lest nothing be said'. But, from the faith point of view, we don't really need this, just as we don't really need to know the ultimate origins of the aliens who planted the titanium cube on Mars, nor the genetic history of the tenth earl. 'How great is God – beyond our understanding!'[36] This is the correct theological reply to those who argue in the manner of Dawkins. Of course it is a deliberately non-intellectual reply, one that will certainly never satisfy a convinced scientific rationalist, and will merely provoke an impatient response. Believers will no doubt have to live with that.

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36 Job 36:26.