Faith&Thought

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In this issue:

FAITH and THOUGHT

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Editorial

We are pleased to include in this edition of the journal the papers read at last year's symposium, which was entitled, ' The Accidental Universe? No Source? No Guide? No Goal?' Dr. Rodney Holder is former Course Director of the Faraday Institute for Science and Religion at St.Edmund's College, Cambridge, where he is a Bye Fellow. His latest book *Big Bang, Big God* (Lion Hudson 2013) is reviewed later in this issue of the journal. Rodney is also an ordained priest of the Church of England. Dr. Denis Alexander is Emeritus Director of The Faraday Institute for Science and Religion, where he is a fellow. His recent books include Creation or Evolution – Do we Have to Choose? (Monarch, Second Edition, 2014) and The Language of Genetics (Templeton Foundation Press, 2011). Malcolm Drummond is a foster carer and charity administrator.

MINUTES of Annual General Meeting for 2013

Saturday 26th October, 2013
Bloomsbury Central Baptist Church, 235 Shaftsbury Avenue, London WC2 HEP

Council members present:	Rev R Allaway	(Chairman)
	Rev J D Buxton	(Hon. Treasurer)
	Rev M J Collis	
	Rev R Holder	
	Dr A P Kerry	(Administrator)
	Mr R S Luhman	(Editor)
	Prof J W Montgomery	(Vice President)

24 other members and three non-members present

OPENING Rev R Allaway welcomed members to the meeting

MINUTES OF PREVIOUS MEETING The minutes of the 2012 AGM were published in F&T Journal, April 2013 (No. 54) The chairman read a summary which was approved and the minutes were signed.

ELECTION The meeting agreed to the re-election of:

a) President (Sir Colin Humphreys),

b) Vice-Presidents (Prof. Malcolm A. Jeeves, Prof. Kenneth Kitchen, Prof. Alan Millard, Prof. D. C. Laine, Prof. J. W. Montgomery)

c) Honorary Treasurer (Rev John Buxton).

Council Membership Notice was given that Dr Alan Kerry has agreed to join the council and will continue to serve as administrator.

ANNUAL ACCOUNTS The annual accounts were presented by John Buxton. A summary sheet was circulated and the full accounts were available for members.

- The accounts were accepted.
- The financial situation is satisfactory.

ANY OTHER BUSINESS The symposium topic for 2014 is being planned for 18th October 2014 and has a working title of **'Homosexuality - Biblical, Scientific and Pastoral aspects'**

CLOSE The meeting closed with prayer and the General Grace at 4:00pm

Sir John Houghton, FRS : An Appreciation

We were sad to hear that Sir John Houghton was stepping down as President of the Victoria Institute. (We were, though delighted to welcome Sir Colin Humphreys, whom he had commended, as his successor.) Somewhat belatedly, we wanted to record our appreciation of him.

I think we are all aware of the valuable work he has done, prophetically challenging the movers and shakers of our world to recognise the effect on God's creation of man-made global warming. He co-chaired the Intergovernmental Panel on Climate Change, which rightly won a Nobel Prize for its work. The Symposium he organised after becoming President was a highlight of the Institute's recent history.

My wife and I knew John as a fellow church member, when we were first married. We recall a humble man, who lived modestly. We have fond memories of him leading a group of us to sing carols to Chinese students in their hall of residence.

After the claimed failure of the Meteorological Office to predict a hurricane, in 1987, the Sun carried a purported interview with John, its then Director General. Their portrait of his was unrecognisable to anyone who knew him. Sadly, he has suffered more serious misrepresentation in the press since then. Seeking to discredit the work of the IPCC, climate sceptics have often accused him of saying something which he never said, attributing it to one of his books, in which it is self-evidently not written.

Since his retirement as Chief Executive of the Meteorological Office, he has had a world role, warning of the likely effects of global warming. John's genuine Christian character and strong evangelical faith give him credibility when speaking to Christians in the USA. This is necessary, as some in the evangelical constituency there are sceptical of such predictions. We were honoured, John, to have played a small part in your valuable ministry.

Rev. Dr. Bob Allaway

Dr.Oliver Barclay

It was sad to hear of the death of Dr. Oliver Barclay on 12th. September 2013 at the age of 94. We pay tribute to a great pioneer from the 1920s. Although he was never on the council of the Victoria Institute, Oliver was a great support and advisor to me when I took over the editorship of 'Faith and Thought' from Dr. R.E.D. Clark in 1984. He wrote a number of reviews and articles including 'A history of the CICCU and personal reminiscences' in a volume devoted to R.E.D.Clark. Oliver was also a founder member of the publishing firm Inter-Varsity Fellowship. I would like to thank him for his inspiration. A full obituary of Dr.Barclay is published in the current issue of 'Science and Christian Belief'

Dr. Brian Robins

Erratum
Endnote 5 of Professor's Vere's article in the previous edition of 'Faith and Thought' should read **Phycology** and not **Psychology.**

Can a Multiverse Provide the Ultimate Explanation?[1]

Rodney Holder

The Big Bang

In the year 1923-24 the Belgian priest and cosmologist Georges Lemaître came to Cambridge to work with Sir Arthur Eddington. During that year he was most likely a member of St Edmund's House. This was later to become St Edmund's College, but then it was a place of residence for Roman Catholic priests studying elsewhere in the University, with a Chapel where they could say daily Mass. Lemaître is rightly dubbed the 'Father of the Big Bang theory'. In 1927 he solved Einstein's equations of general relativity for the universe as a whole, and came up with an expanding universe solution. His paper was published in a rather obscure journal in French and not widely known until Eddington republished it in *Monthly Notices of the Royal Astronomical Society* in 1931. Meantime the expansion had been observed in 1929 by Edwin Hubble.

Lemaître came up with a further solution in 1931 which indicated that the universe should be expanding from an original 'creation event' which we now know occurred some 13.8 billion years ago. This is the Big Bang theory proper, though that phrase was only coined much later by atheist British cosmologist Sir Fred Hoyle, who hated the idea because he thought, if the universe had a beginning, then that implied God created it. Einstein himself disliked the Big Bang idea and had come up with a solution to his equations which was static. He did this by introducing an extra term in his equations, the cosmological constant, and setting it to a particular value. He was later to call this his biggest blunder.

In fact the Big Bang theory is extremely well supported by the observational evidence. The expansion of the universe is the obvious piece of evidence. However, that wasn't enough for a group of atheist cosmologists in Cambridge, Hermann Bondi, Thomas Gold, and, most famously Fred Hoyle. These cosmologists proposed an alternative theory, the steady state theory, whereby the universe has always existed, always looking pretty much the same, and the gaps caused by the expansion are filled by new matter continuously created at just the right rate to fill them.

The steady state theory has been demolished and the Big Bang established by several subsequent strands of evidence. The most important piece of evidence is that the theory predicts a uniform, remnant radiation field bathing the universe. On the Big Bang theory the universe would have been very dense and hot at the beginning, and has now cooled to a mere 3 degrees above absolute zero. This cosmic microwave background radiation was predicted to exist in 1948 by Ralph Alpher and Robert Herman and was observed by Penzias and Wilson in 1965, effectively eliminating the steady state theory which could not explain it.

It seems to me that modern cosmology poses two fundamental questions which take us beyond the science. I have already hinted at the first, which is that the Big Bang seems to indicate that a finite time ago, some 13.8 billion years ago, the universe began to exist. The second is the so-called fine-tuning, which I shall describe shortly. Philosophically, the temporal beginning relates to the cosmological argument for God's existence, whereas the fine-tuning relates to the design argument, but these modern scientific discoveries give a new twist to each of these traditional arguments. Let's begin at the beginning.

What do we make of the beginning?
According to the Big Bang theory, space and time came into existence together some 13.8 billion years ago. It is interesting to compare the theory with what Christian priests and theologians from the past have said about creation. Thus St Augustine, round about 400 AD, wrote this: 'And if the sacred and infallible Scriptures say that in the beginning God created the heavens and the earth … then assuredly the world was made, not in time, but simultaneously with time.'[2] Augustine saw God as outside or transcending the space-time realm of the universe he created.

The idea that the universe had a beginning is troubling to some atheist physicists. Fred Hoyle hated the idea. So today does Stephen Hawking. Hawking says that if the universe had a beginning then it would need God to create it. He and a colleague James Hartle have come up with a model in which time becomes imaginary near the beginning. Hawking thinks this so-called 'no boundary' proposal does away with a beginning and therefore with any need for God. Here is what he says, quoting from *A Brief History of Time*:

'So long as the universe had a beginning we could suppose that it had a creator. But if the universe is really completely self-contained, having no boundary or edge, it would have neither beginning nor end; it would simply be. What place, then, for a creator?'[3]

In his more recent book *The Grand Design*, co-authored with Leonard Mlodinow, Hawking says the same thing: a universe with no beginning in time has no need for God to 'light the blue touch paper' to set it going.[4]

There are serious scientific and philosophical problems with Hawking's proposal. Not least is the idea of imaginary time. Another very serious challenge comes from a theorem of Alexander Vilenkin and others, according to which, under quite general conditions, a singularity must exist at some finite time in the past for all the major theories currently on offer in cosmology. These include 'multiverse' theories such as those I shall go on to discuss later in the context of fine-tuning. A singularity is a point of infinite density and zero size where the laws of physics break down and it marks the beginning of time.

Ironically Vilenkin reaffirmed the results of his theorem at a meeting in Cambridge in early 2012 to celebrate Stephen Hawking's seventieth birthday, as reported by Lisa Grossman in *New Scientist.*[5] Sadly, Hawking could not attend because of illness, but in a pre-recorded message he had said this, in line with his earlier statements: 'A point of creation would be a place where science broke down. One would have to appeal to religion and the hand of God.' Vilenkin, however, is reported as saying, 'All the evidence we have says that the universe had a beginning'.[6]

Having said that, there is also a theological objection to Hawking, and indeed to the whole line of argument towards atheism based on avoidance of a beginning. And that is essentially because the Christian doctrine of creation is much more about ontological origin—why is there a universe at all—than about temporal origin.

In the thirteenth century St Thomas Aquinas recognised that God would be the cause of the universe's existence even if it had no beginning in time. He thought that it can neither be proved nor disproved that it had a beginning, but he himself believed it does from Genesis,[7] although, in fact, Genesis is not clear cut.

For Aquinas there can be an infinite chain of causes going back in time, but that infinite chain needs a cause for its existence. And God provides the first cause because he himself exists by necessity as I am about to explain. Aquinas did believe in a beginning of the universe, because that's how he read Scripture, but his argument is framed in logical, not temporal, terms.

Ultimate Explanations – Why is There Something Rather than Nothing?

By an ultimate explanation I mean an answer to just this question, 'Why is there something rather than nothing?' 'Why is there any universe at all?' In their book *The Grand Design* Hawking and Mlodinow claim that science can answer that question, and Lawrence Krauss says the same in his book *A Universe from Nothing.*[8] In fact Krauss redefines nothing to be a rather sophisticated something, namely the quantum vacuum, which is in reality a hive of activity with particles spontaneously coming into existence and annihilating again, so he has not really explained how something comes from nothing at all. I have likened this ontologizing of 'nothing' to the way 'nobody' is most confusingly and amusingly ontologized in *Through the Looking Glass.*[9]

Of course the idea that the universe can create itself out of nothing is logically self-contradictory. Apparently, say both Krauss and Hawking, gravity can do the trick because its negative energy balances the positive energy needed to create matter.

However, this sleight of hand does not mean that the universe creates itself out of nothing, and if gravity and the laws of nature were responsible, one really would still be entitled to ask where these come from in the first place and, indeed, the quantum vacuum on which they act.

The fact is that only God can provide the ultimate explanation. No scientific theory can do that. The answer to the above question is that there is a universe because God freely created it. He wanted to bring about an environment in which free, rational creatures could flourish and have a relationship with him.

I am now going to introduce two important terms from philosophy, the terms 'necessary' and 'contingent'. Something is said to be necessary if it cannot be other than it is; something is contingent if it can be otherwise or if it need not exist at all.

Aquinas and many other theologians since have argued that it is the idea of God as 'necessary being' which provides a stopping point for explanation. To say that God is necessary means that he cannot but exist. He must exist. He cannot not exist. This is what the concept 'God' means. Another way of saying it is that there is no possible universe in which God does not exist. It follows from this that God was not himself created. He could not have been or else there would have been a time when God did not exist but something else did, namely whatever or whoever created God. Anything created is not God. Now someone could doubt that such a being exists—we know that many do doubt it, but it follows that if he does exist then he has always existed and will always exist and everything else that exists depends on him.

That is because everything else is 'contingent'. The word contingent means the opposite of necessary. Something which may or may not exist is contingent. It did not have to exist. It might not have existed. And even if it exists it could be different from what it is.

Things are very different with the universe from the way they are with God. The universe is contingent. It might or might not have existed. Hawking put this very eloquently himself back in *A Brief History of Time*, when he wrote: 'What is it that breathes fire into the equations, and makes a universe for them to describe?'[10] That is a fundamental question. Cosmologist Martin Rees, Lord Rees of Ludlow, recognises that it cannot be answered by physics. 'Such questions lie beyond science', he writes: 'they are the province of philosophers and theologians'[11]. Interestingly the same point was made in 1978 by Dennis Sciama, who supervised the doctoral theses of both Hawking and Rees (incidentally, I also had the privilege of being supervised by Sciama who was a great and inspiring cosmologist). Speaking as a scientist Sciama said this: 'None of us can understand why there is a Universe at all, why anything should exist; that's the ultimate question.'[12]

That is correct. Science is powerless to explain why the universe exists. The universe cannot explain its own existence. It cannot create itself, by lifting itself up by its own bootstraps, as it were, into existence. However, theism can explain why there is a universe and it can explain the particular character of the universe—it was created by God, who freely chose to make this particular universe with all the properties needed for it to produce life. Of course, theism would explain the existence of any other universes than our own too, whether they produced life or not, since exactly the same reasoning would apply. We have thus already answered the question in the title of this paper. However, there is more to say, and this leads me into the second area where cosmology interacts with theology.

Specialness of the Big Bang: Cosmic Fine-tuning

The Big Bang theory is very well supported by the evidence, yet it presents us with some puzzles. It seems to be set up in a very special way indeed, seemingly in order for us to be here to observe it. This specialness relates to two areas:

(1) First, the conditions right back at the beginning, shortly after the big bang, need to be just right to high degrees of accuracy for the universe to give rise to life.

(2) Secondly, the constants which go into the laws of physics need to take the values they do, in order for the universe to give rise to life. These constants determine the relative strengths of the four fundamental forces of nature, namely gravity, the electromagnetic force which holds atoms together, the weak nuclear force responsible for radioactive decay, and the strong nuclear force which binds atomic nuclei together. They also include such quantities as the masses of the fundamental particles. They determine how key physical processes go at different stages of the universe's evolution.

There are many, many examples of this so-called fine-tuning, and I will just give you one of each kind now:

(1) First, right back near the beginning, at one second after the Big Bang, the mean density of the universe has to be just right, i.e. very close to a certain 'critical density', to 1 part in 10^{15}. If it is smaller than it is by this amount then the universe will expand far too quickly for galaxies and stars to be able to form. If it is greater then the whole universe will recollapse under gravity long before there has been time for stars to evolve. Either way you have a boring universe with no possibility of life. If one naively extrapolates back to the earliest time we can speak of, 10^{-43} seconds from the beginning, when an as yet unknown theory of quantum gravity is required to describe the universe, then an accuracy of 1 in 10^{60} is required.

(2) Secondly, the strong nuclear force, which binds atomic nuclei together, has to be just right for carbon and oxygen to be made inside stars. One of the great discoveries in astrophysics is how all the chemical elements are manufactured inside stars, where the temperatures reach hundreds of millions of degrees, through nuclear reactions. Sir Fred Hoyle, the atheist Cambridge astrophysicist I mentioned before, was foremost in this discovery, and he it was who discovered the particular 'coincidences' required for carbon to be made in the first place, and then for the carbon not to be destroyed in making oxygen. When he made this discovery he was moved to remark that 'a superintellect had monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature.'[13] This is a man who earlier in his life described religion as an illusion.

As I say, there are a host of these examples of fine-tuning on which I shall not elaborate in detail. But just to mention a few: the universe needs to be the size it is, with a hundred billion galaxies in order for there to be life. A universe with only one galaxy, which you might think provided enough stars and planets for life, would be hopeless because such a universe would have expanded for only about a month. The mass of the proton needs to be very close to 1840 times the mass of the electron, as it is in fact, in order for there to be any chemistry possible at all, let alone the development of life. And so on, and so on. Some more examples will crop up later.

The cosmologist Paul Davies puts it like this: 'Like the porridge in the tale of Goldilocks and the three bears, the universe seems to be "just right" for life, in so many intriguing ways.'[14]

Explanations for the Fine-Tuning

This specialness of the universe, which is essential if there is to be life, just cries out for explanation. The most obvious explanation is the theistic one, that it was made that way; it was designed so that life would appear. Christians would say that God intended there to be living creatures with the capacity for reason and with free will, who would be able to have a relationship with him.

Many scientists, however, regard any kind of design hypothesis, even this one, with loathing. They want to restrict their explanations, even for why the laws of physics are as they are, to within science itself.

So what alternatives have scientists come up with? I am going to contrast two strategies which scientists have pursued in order to avoid the implication of design by God.

(1) The first is to seek an explanation from within science for the values taken by the various constants of physics—to derive them from some more fundamental theory, a so-called 'theory of everything' (TOE). Interestingly Einstein spent

his later years in a fruitless search for such a theory: 'What I am really interested in is whether God could have made the world in a different way', he said—although this quote obviously indicates that he still saw no contradiction with God being behind it all. Connected with this search for a TOE, though different from it, is the aim to show that the initial conditions are not special: to argue that whatever they were, the universe would turn out much the same.

(2) The second strategy is diametrically opposed to this. It is to postulate a multiverse. A multiverse is vast, usually infinite, ensemble of existent universes, embracing the whole range of values of the constants and initial conditions. The idea is that if a multiverse exists you can then say: Hey presto! Given the vast ensemble, our universe with its suite of parameters is bound to exist, and we should not be surprised to find ourselves in it, because we simply couldn't exist in the overwhelming majority of universes which differ from ours in their parameter values to the slightest degree.

Strategy (1) can be further divided into two distinct versions. In the first version, the constants can be derived from a more fundamental theory, but it is still the case that alternative theories exist and could apply to alternative universes. In that case the basic problem remains. The question, why do the constants take the values they do, is simply modified to, why does this particular Theory of Everything (TOE), which gives rise to just the right values for the constants, and hence to life, apply? Why is this particular TOE put into effect in a universe?

The second version is much more radical and makes a much bolder metaphysical claim. This is that there is only one self-consistent set of physical laws, and the constants pertaining in these laws necessarily take the values they do—they are calculated from the one and only self-consistent TOE. Thus the universe could not have been different, so, with the big proviso that it exists, then it is necessarily the way it is—and that is because the TOE is taken to comprise the only self-consistent theory and set of parameters there is.

Philosopher Peter van Inwagen gives a helpful analogy to bring out the huge sense of surprise this would give rise to. Imagine a thousand by thousand square grid. Write the first million digits of π consecutively into the grid. Then colour the grid by assigning a different colour to each of the digits 0, 1, 2, 3, ..., 9. Suppose the result is a painting of surpassing beauty, something like the Mona Lisa. That would be utterly astonishing. But the picture is necessary given that the digits of π are necessary. But it would still be immensely surprising if you got the Mona Lisa rather than an amorphous mess. Of course given that the digits of π never repeat, there will be some sequence of a million digits way down the line which yield a beautiful pattern, but if the first million did that would be totally amazing. Similarly it would be totally amazing if the necessary Theory of Everything gave rise to a universe with life.

Coming to strategy (2), the multiverse hypothesis says that the universe certainly can be different and indeed different universes actually exist. And it could be the case that the more universes you have the more chance there is of getting one with life. But there is a pretty big puzzle here too, namely, 'Why does this particular multiverse exist as opposed to another?' We now have a choice of equations into which fire somehow gets breathed, and we have a choice about how many sets of equations give rise to universes and how many universes they give rise to. What determines these choices?

One cosmologist, Max Tegmark, has proposed in answer to this that all possible mathematical structures have physical existence. That would certainly guarantee our universe's existence. But it takes us way beyond what physics can tell us and most mathematicians and physicists think the idea is incoherent. You soon run into problems and paradoxes when you actually start to try and write down 'all possible mathematical structures'. Certainly there seem to be conflicts in what actually exists as opposed to what can possibly exist. For example *I* cannot simultaneously be sitting in my study writing an article on 'Can a Multiverse provide the Ultimate Explanation?' *and* be enjoying an exotic holiday trekking in the Peruvian Andes. Some copy of me in another universe could conceivably have taken a different course, but *I* couldn't simultaneously do both.

Recent Developments in Cosmology

A now widely accepted way to solve some of the problems with the standard Big Bang, and the fine-tuning , was proposed by Alan Guth and is called the theory of inflation. This postulates that the universe underwent an incredibly rapid period of accelerating expansion—called inflation—from 10^{-35} to 10^{-32} seconds after the origin. In that time the universe expanded from being 10^{-25} cm to 10 metres across. At that point the much slower deceleration of the classical Big Bang took over. Now it is the case that such a rapid period of accelerating expansion, even if that short, drives the density of the universe to the critical value and smooths out the differences between different parts of the universe, solving another problem to do with the universe looking the same in all directions.

That sounds wonderful, but there were some serious problems with inflation, as originally conceived. One serious problem from our point of view is that inflation itself needed fine-tuning, i.e. parameters to be chosen specially! That is not very satisfactory for a theory which was meant to solve the problem of the need for fine-tuning. The upshot is that there has been an enormous inflation in the number of inflation theories—well over a hundred at the last count.

The next step was to propose that some parts of the universe inflate and others do not and at different rates where inflation does occur. This is a turn from strategy (1) to strategy (2), namely a multiverse with different regions (which get labelled universes in their own right) having different parameters. The idea is that this scenario is bound to give rise to regions conducive to the development of life. This picture was proposed by a Russian cosmologist now working at the University of Stanford, California, Andrei Linde. His idea is known as chaotic inflation. Another variant is eternal inflation in which infinitely many different bubble universes are formed by inflation with bubbles forming within bubbles ad infinitum.

Now we are still not quite at the Theory of Everything (TOE). That is the theory which is said to apply to the very first 10^{-43} seconds from the origin. During that time one needs a theory which combines all the forces of nature. That is to say, it combines Einstein's general theory of relativity, which is the theory of gravity, with quantum mechanics, which applies to the other forces and describes the very small.

We do not know what that theory is but the leading contender is string theory. String theory postulates that the ultimate building blocks of matter are not point-like particles but tiny, one-dimensional objects called strings. By tiny I mean really tiny, some 10^{-33} cm across. String theory aims to solve some of the problems with the standard model of particle physics, especially the existence of infinite quantities like mass and charge. The elementary particles we observe are actually different modes of vibration of the strings. An important complication is that these vibrations occur in more than the three dimensions of space that we are used to. The reason we only see three extended dimensions is that these other dimensions get curled up very small. Quite why this is so remains something of a mystery.

The original aim of string theory was to calculate particle masses, i.e. strategy (1) was pursued. The theory has always been dogged by its lack of connection with observation and experiment so the main motivation has been that it is beautifully mathematically elegant and it solves some theoretical problems. It is still the aim of some string theorists to calculate everything and some believe that is possible in principle, though some parameters (like the cosmological constant) still seem to need strategy (2). Nevertheless nothing has been calculated in practice so some string theorists, notably Leonard Susskind, have taken the turn to strategy (2).

Susskind and his colleagues talk about the 'landscape of string theory'. They find that there is not just one but many solutions of the theory, anything from 10^{100} to 10^{1000} solutions, with 10^{500} as somewhere in between. The further claim is that a universe can 'tunnel' between solutions. The solutions are stable for billions of years, then another universe pops up as a region moves to another solution of the equations. This feeds in very neatly to the eternal inflation idea. If it works, and it is a big if, eternal inflation would be the means whereby the string theory landscape is populated. It is also true that if there is a theory which in some sense naturally gives rise to many universes, then that gives plausibility to the idea of a multiverse.

There are a number of other multiverse models out there, which puts me in mind of remark that was once made by the great Russian physicist Lev Landau that 'cosmologists are often in error, but seldom in doubt'. With the proliferation of models and lack of observational constraint, it seems there is a considerable degree of truth in this!

Problems for Multiverses

Some Christian scientists and philosophers favour the idea of a multiverse. However, to me the whole idea, including the latest string landscape concept, is fraught with problems, which I now list in what follows.

1. It is important to recognise that the physics is speculative, to say the least. Even the string theory community is divided over whether the landscape exists. Some think the solutions are really different theories and therefore to talk about tunnelling from one to another is quite wrong. The trouble with multiple universes is that they cannot even in principle be observed. They cause no effect whatever in our own universe because no signal from them can ever reach us.

   Martin Rees, whom I mentioned earlier, is one of Britain's most distinguished cosmologists. In one of his books he describes himself as a 'cautious empiricist' who starts to feel at home when familiar physics can be applied to the universe, which he says is the first thousandth of a second from the origin and later[15]. However, in another book he expresses his preference for a multiverse over design, even though he describes the multiverse idea as 'highly speculative' and his preference 'no more than a hunch'.[16] The physics which would yield multiverses applies not to one thousandth of a second after the origin, but the first 10^{-32} seconds or even the first 10^{-43} seconds. It is a quite interesting example of an ideologically driven rather than evidence based preference. Even though Rees recognises that science cannot answer the question why there is anything at all, he still opts for a multiverse as apparently removing the need for God. Leonard Susskind, whom I mentioned earlier as one of the founders of string theory, likewise sees no need for God if his string landscape version of the multiverse is correct.

2. There is a problem with the existence of actual infinities in nature. Mathematicians happily talk about and manipulate different degrees of infinity but there are many paradoxes when one starts to think about infinite numbers of things existing in the real world. Hilbert's Hotel has infinitely many rooms all of which are full. Even so, you can very easily make room for infinitely many more guests! All you have to do is tell the person in Room 1 to move to Room 2, the one in Room 2 to go to Room 4, the one in Room 3 to go to Room 6, and so on. Then all the even numbered rooms are full but the odd numbered ones are all free! There is also Russell's paradox of the set of all sets which are not members of themselves.

   One problem is that, if there are infinitely many regions with varying parameters there will be infinitely many identical copies of me, a notion I have already mentioned above. There will also be copies who differ very slightly. Some of the 'Is' will be writing about multiverses; other will be trekking in the Peruvian Andes instead. It is quite bizarre even to begin to think about this. Some philosophers and mathematicians think infinitely many universes are ruled out because of the paradoxes. I do not quite see the paradoxes as logically precluding them, but a theory without paradoxes is surely to be preferred.

3. The multiverse hypothesis is not a simple hypothesis. Scientists normally opt for the simplest of competing hypotheses and this does not seem to be that. The principle of Ockham's razor tells us that we should not multiply entities needlessly. As I remarked earlier, another question one needs to ask is 'Why this multiverse?' That applies to the string landscape idea as much as any of the others, and already to produce the landscape some choices within string theory have been made.

4. In any case the turn from strategy (1) to strategy (2) implies a move away from predictability, which had been a cornerstone of the scientific method. This is not just predictability of physical parameters, but predictability in general based on the existence of order in the universe. Suppose some unexplained feature arises in the laboratory. Instead of trying to explain it rationally using science, the temptation is now to say, 'We just happen to be in a universe which exhibits that feature'. Such theories are not falsifiable (though see point 6 below).

5. Possibly the most outstanding problem in cosmology is the fine-tuning of the cosmological constant, Λ. This is the term originally introduced into his equations by Einstein to make the universe static. If he had put it to zero he would have predicted the expansion and arrived at the Big Bang theory.

   Until very recently it had been thought that Λ was zero. More recently observations have indicated that Λ might take a very small, but positive value.

   Physicists think they know where Λ comes from. In quantum theory the vacuum is not empty but a hive of constantly fluctuating activity, and possesses energy. Λ is believed to be the energy of the vacuum. The unfortunate thing is that when Λ is calculated it gives a value 10^{120} times that which is compatible with observations. If Λ really took the calculated value you would be pulled apart in an instant with your body parts flying away to the ends of the universe.

   The answer cosmologists have come up with to this one? You may not by now be surprised to learn that it is a multiverse. In the string theory landscape the different universes represent different values of Λ. If a universe starts with a very high value of Λ it will spawn billions upon billions of universes until a universe eventually arises with the small value of Λ that our universe has.

This looks like a great success. But now there is another question we need to ask. According to the multiverse theory, the universe should be regarded as typical of those with Λ values which permit life. It is a random member of the subset of universes which give rise to life. The question then is, 'Does it look like it is that or is it more special than that?'

Calculations show that the average value of Λ which would be compatible with life is quite a bit more than the value we observe. The first calculations showed that it could be a hundred times more; that figure came down with more recent calculations but it still looks a bit too high. Thus we seem to be observing a value of Λ that is a bit too special to be explained on the basis of a multiverse, though not enormously so by astronomical standards.

Of course there could be many other parameters of our universe besides Λ which are more highly tuned than is strictly required for our own existence. It looks as though there are and I shall return to one of them in a moment.

6. Some multiverse models require an element of fine-tuning for there to be a multiverse in the first place. An example is that the overall mean density must be less than or equal to the critical value so that the universe as a whole is infinite and expands forever. And that may not be likely given that in principle the density can take any value from an enormously large range. It might well be greater than the critical value, in which case the universe is not infinite, but finite.

It may be that the landscape and other multiverse theories are already faced with the possibility of observational falsification for this reason. Data on the cosmic background radiation from the WMAP satellite has been examined in detail. The very tiny fluctuations in it have been taken to confirm the predictions of inflation. But there is a discrepancy, namely that the fluctuations are much weaker than expected at large angular scales. That could mean that we are living in a finite universe which is closing back in on itself. What this would be saying is that we could almost be seeing right round the universe and there simply wouldn't be other regions 'outside' ours. This is very tentative and controversial, but the model which is proposed here at least has the merit of contact with observation and openness to empirical enquiry—and would avoid all the paradoxes of infinity.

In fact, the more recent Planck satellite confirms weak temperature fluctuations at large angular scales, and other anomalies in the cosmic background radiation, but does not seem to support this particular model.[17]

Suppose, then, that this particular finite model were indeed eliminated by observation. It would still be the case that we could never be sure that we really inhabited an infinite universe. John Barrow makes just this point.[18] In fact either of two options is possible. We may think we are in an infinite universe when we just inhabit an underdense part of a finite universe *or* we think we are in a finite universe when we inhabit an overdense part of an infinite universe.

7. Roger Penrose poses a massive problem to inflation and indeed all attempts to explain the specialness of the Big Bang on the basis of a multiverse.

Penrose is concerned with the amount of order there was at the beginning. Order can be measured (by a quantity called entropy) and it decreases over time. Penrose puts it like this concerning the entropy of the universe. He says that the Creator had something like $10^{10^{123}}$ possible universe configurations to choose from, only one of which would have the order which ours does. That is the order necessary to produce a cosmos with all the galaxies, stars and planets that our universe possesses.

Now Penrose points to the fact that, for a universe to have life, you actually need a great deal of order but much less than this vast amount. You could create the entire solar system with all its planets and all its inhabitants by the random collisions of particles and radiation with a probability of 1 in $10^{10^{60}}$. This is a tiny probability but much greater than 1 in $10^{10^{123}}$. The implication is that our universe is vastly more special than required merely in order for us to be here. It is much, much more special than a universe randomly selected from the subset of universes which are conducive to life. This is a very serious challenge for the multiverse idea but totally consistent with design.

To summarize this point, if the multiverse explanation is correct then we ought to be in a universe with parameters just right for us but not vastly too special. The cosmological constant looks close to meeting this criterion but the initial entropy of the universe fails catastrophically. There are other parameters such as the constancy of the charge on the electron and the lifetime of the proton which also look much too fine-tuned, again posing a problem for the multiverse hypothesis.

8. Given a multiverse, it turns out that we are much more likely to be in a fake universe, simulated by some super-intelligence, rather like in the film *The Matrix*, than a real universe. That is because, as Paul Davies says, as soon as we even entertain the possibility of a multiverse, there seems no good reason

to rule out universes which contain computer simulations of other universes.[19] And these simulations or fake universes are far, far cheaper in energy terms to manufacture than real universes—hence they are likely to be overwhelmingly dominant among universes as a whole. However, rather than this quite bizarre possibility, surely the simpler explanation, as with all these problems, is that there is one super-intelligence, the unique necessary being of traditional Christian theology, who because he is perfectly good and trustworthy creates one, real universe.

Comparing the Explanations

So how do we choose between the multiverse explanation and creation and design by God? I have just listed a host of problems with the multiverse explanation in addition to the fact that no purely physical explanation will ever be ultimate.

In contrast creation and design by God does provide an ultimate explanation because God, if he exists, exists necessarily—that is at least part of what we mean by 'God'. In addition design by God is a simple explanation, and much more economical than the multiverse. One is not invoking a whole multitude of complex entities with which one can have no possible interaction, but one intelligent being, like ourselves in some ways but so much greater, a being of unlimited power and knowledge (omnipotent and omniscient in classical terms), and perfectly good. Out of all possible universes, God freely chose to create this particular universe with the deliberate intention of its bringing forth creatures for a relationship with himself, and so is likely to have created an ultra-special universe for the purpose.

Let me end by bringing us right back to Georges Lemaître, the Father of the Big Bang. He had a wonderful quote which summarises for me both the scientific and theological quests:

'There were two ways of arriving at the truth. I decided to follow them both.'[20]

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Order and Emergence in Biological Evolution.

Denis Alexander

I will start by providing a brief summary of the arguments that I will be presenting in this chapter. First, I will give a brief overview of the idea of Progress that has so often been attached to the narrative of the biological theory of evolution and I will argue that the outcome of that particular discussion makes relatively little difference to Christian theology. Second, I will refer to more recent commentators who have suggested that Darwinian evolution is incompatible with either the ideas of Progress or of Purpose, or of both. Third, I will suggest that in contrast to these commentators, recent biological insights point to evolution as a highly constrained process, consistent with the idea of a God who has purposes and intentions for all of His created order. In the dynamic interplay between chance and necessity that characterizes the evolutionary process, it is necessity that has the upper hand. Therefore, whatever one might think about the discussion about Progress, as far as Purpose is concerned, the biological data do not support those who suggest that evolution is incompatible with the idea of Purpose.

The Question of Progress in Evolutionary History

First, Progress. The idea already had a long and complex history for more than two millennia before biological evolution came on the scene, with many nuances in meaning, then as now. At the societal level it generally expressed the assumption that humanity was making social, economic, scientific and political advances and that these trends were likely to continue on into the future. Within the context of natural history the idea of progress was focused more on the upward climb of organisms, from the simplest to the complex, from "monad to man". The problem is that these two ideas of progress have often become inextricably entangled, with either the more social and political sense framing the narrative within which the biological story has been told, or the biological story generating or justifying accounts of human social and political progress, or a synergistic interaction between the two in which the social and biological narratives became interdependent.

A Christian vision for the idea of progress was famously stated by Augustine in what is arguably the first full-blown book on the philosophy of world history, *The City of God:* "The education of the human race, represented by the people of God, has advanced, like that of an individual, through certain epochs, or, as it were, ages, so that it might gradually rise from earthly to heavenly things, and from the visible to the invisible." (Augustine and Dods 2009). That same Christian vision framed the scientific revolution of the 17^{th} century, which was strongly progressionist in tone, even though it was often presented as a concerted attempt to recover the knowledge that had been lost at the Fall (Harrison 2007). As Francis Bacon proclaimed: "When he [Aristotle] had made nature pregnant with final causes, laying it down that 'Nature does nothing in vain, and always effects her will when free from impediments', and many other things of the same kind [he] had no further need of a God' (Bacon and Wright 1963). In that case, Bacon argued "There [is] but one course left....to try the whole thing anew upon a better plan, and to commence a total reconstruction of sciences, arts, and all human knowledge, raised upon the proper foundations". Bacon's *New Atlantis* published in 1624 (Bacon and Smith 1900) was a Utopian vision of life in which the benefits of science are used for the common good, established 'for finding out the true nature of all things, whereby God might have the more glory in the workmanship of them' whilst the practical application of knowledge was 'for the comfort of men'.

The optimism displayed by the 17^{th} Christian natural philosophers is, in retrospect, startling. John Wilkins, a founder member of the Royal Society in Britain, wrote a book in 1638 on 'The Discovery of a New World', remarking that 'without any doubt some means of conveyance to the moon cannot seem more incredible to us, than overseas navigation to the ancients, and that therefore there is no good reason to be discouraged in our hope of the like success' (Hooykaas 1977). Kepler was quite sure that as soon as man mastered the art of flying, then human colonies would be established on the moon.

Meanwhile the discoveries of the microscope were opening up visions of the minutiae of the biological world in remarkable detail. But it was a world that still remained framed within Aristotle's 'Great Chain of Being' (*Scala Naturae*) in which the hierarchical order of creation, created by God at the top, was arranged in a vast systematic classification of angels, then Man, then animals, then plants, then minerals at the bottom. When Linnaeus published his great classification system in 1737, it was arranged according to the three familiar lowest classes of the *Scala Naturae*: animals, plants and minerals.

The static *Scala Naturae* hardly seemed a recipe for progress, but it was eventually this scheme that became transformed into Darwin's tree of life. As Wallace, Darwin's co-discoverer of natural selection, was to write in his 1865 paper entitled 'On the Law which has Regulated the Introduction of New Species': "Every species has come into coexistence coincident in both space and time with a pre-existing closely allied species" (Berry 2013). It was the brilliance of both Wallace and Darwin to bring history into biology, so that historical links now began to appear in the Great Chain of Being, joining it up as evolutionary history rather than as mere classification.

But first there had to be a readiness to accept change. The seeds were sown by the willingness of the 17th century natural philosophers to question the ancients and "to commence a total reconstruction of sciences". In natural history, however, change began to take on some alarmingly materialistic connotations. This was seen most dramatically in the debates about reproduction between the so-called preformationists and epigeneticists that characterized the first half of the 18th century (Roe 2010). 'Preformationism' referred to the belief that new organisms came from "germs" which represented preformed organized matter that had originally been brought into being by divine creation, and the idea gained popularity as a reaction against Cartesian mechanical views of reproduction. As Roe reports, "Encased within one another (the theory of *emboîtement*), all "germs" existed in the first member of each species. By involving God's creative power in every future instance of reproduction, preformation came to be seen by many as a bulwark against the immorality to which atheism would inevitably lead" (Roe 2010). By contrast the epigeneticists saw the generation of each new organism during reproduction as entailing the formation of new order out of disorganized matter, but this was thought by many to open the door to materialism and atheism. Matter began to be seen by some as self-creating and self-energising, an idea that gained further traction with Abraham Trembley's discovery in late 1740 that the small fresh-water polyp could self-regenerate after being cut up into separate pieces. Furthermore, in the early 1740s, John Turberville Needham observed that when he added water to blighted wheat, fibers appeared to come to life like tiny worms that moved in a twisting motion for several hours. These observations created a sensation and in France the Encyclopedists such as Denis Diderot (1713–84) and Paul-Henri Thiry d'Holbach (1723–89), embraced such ideas of self-organising matter and incorporated them within their radical anti-clerical narrative in which a new natural basis for morality and society would emerge. The theme of change and progress, which was so central to the writings of the French *philosophes*, therefore became associated with a materialistic natural history in which matter acquired new powers. Animals developed from the moist earth heated by the sun. There was no need for God. For Diderot, Needham's microscopic observations provided the model for a world based on ceaseless activity and change, rather than preordained stability, and it was change associated with progress, progress in which the old static social order would be destroyed and a new world order ushered in that would lead to toleration and justice.

Unfortunately the great chemist Antoine Lavoisier (1743-1794), one of the founders of the modern sciences of both chemistry and biochemistry, did not experience much toleration in the revolution that followed, losing his head in the process. Someone who disdained Lavoisier's chemistry, though in a way quite unconnected with his abrupt demise, was Jean-Baptiste Lamarck (1744-1829), who was more fortunate, and it is with Lamarck that the story of evolution in the form of a systematic theory really begins. Lamarck was much influenced by the *philosophes* and by their idea that physical laws produce complexity and progress. His mentor was the Comte de Buffon, one of the top French natural philosophers of his day, and Buffon's support earlier in Lamarck's career eventually led to his appointment in 1793 as one of the twelve professors in the newly organized Musée National d'Histoire Naturelle (National Museum of Natural History). Lamarck drew the short straw and was appointed Professor of Lower Animals (insects and worms), a topic of which Lamarck knew little, his own previous expertise being more in the area of botany. But he set about the study of his new field with great enthusiasm, inventing a new word - 'invertebrate' - to describe the objects of his study, and it was these investigations that led him to forsake his previous belief in the fixity of species and to become an evolutionist, as he stated in his introductory lecture for his new post given in 1800. Lamarck followed this up by three major publications in which evolution is presented in strongly progressionist terms, but ironically Lamarck himself, an ardent materialist, was also a convinced uniformitarian. To bring these two apparently incompatible ideas together, Lamarck envisaged the continuous spontaneous generation of the simplest organisms at the bottom, which then move up the escalator of life, with all steps occupied at all moments. In the newly minted Newtonian universe, there was a force that perpetually tends to make order (*Le pouvoir de la vie* or *la force qui tend sans cesse à composer l'organisation*) As Lamarck himself expressed his theory:

"Ascend from the simplest to the most complex; leave from the simplest animalcule and go up along the scale to the animal richest in organization and facilities; conserve everywhere the order of relation in the masses; then you will have hold of the true thread that ties together all of nature's productions, you will have a just idea of her pace, and you will be convinced that the simplest of her living productions have successively given rise to all the others." (Lamarck and Drouin 1986).

Lamarck, unlike his colleague Georges Cuvier (1769-1832), did not believe in the extinction of species, and so in the progressive evolution of life, space was made available on the next step of the escalator by everything moving up in turn. When species disappeared it was because they had evolved to something different. When the environment changed, different organisms gradually adjusted their behaviours to thrive better in their new environments, and their adaptations were then inherited. This entailed a gradual move upwards towards increasing complexity and, in the end, perfection. As Lamarck wrote in *Philosophie zoologique*, "Nature, in producing in succession every species of animal, and beginning with the least perfect or simplest to end her work with the most perfect, has gradually complicated their structure" (Lamarck and Martins 1873). The Great Chain of Being had acquired an engine.

Charles Darwin's own Grandfather, Erasmus Darwin (1731-1802), poet, rationalist, botanist, to some degree foreshadowed Lamarck, in his work *Zoonomia* (1794-6) envisaging that all living animals had arisen millions of years before man from one "living filament" which the great First Cause had endowed with the potential for delivering "improvements by generation to its posterity, world without end!". In Erasmus' poetry we start with "Organic Life beneath the shoreless waves" and finish with "Imperious man, who rules the bestial crowd.." Life is always on the up. Yet as far as is known, Erasmus Darwin and Lamarck's evolutionary theories arose independently. Perhaps it is just that Progress was in the air.

Although Lamarck died a pauper and the significance of his work lay unrecognised during his life-time, Lamarckian themes gained great notoriety in later decades of the 19th century, not least when they were picked up by the Scottish publisher Robert Chambers in his then anonymous *Vestiges of the Natural History of Creation* (1844). Chambers presented his readers with a developmental hierarchy, which he termed the "universal gestation of nature". It was basically a story of the evolution of everything. In the sky a swirling fire-mist evolved into nebulae, solar systems, and planets; on the ground invertebrates, fish, reptiles, mammals, and man followed in order up life's great escalator; and in society there was development in civilization as Negro, Malay, American, Indian, Mongolian and Caucasian gave way one to the other. The book was a sensation and it wasn't until the 1890s that the sales of Darwin's *Origin of Species* began to catch up with Chambers' popular work, despite, or perhaps because of, being lambasted by all the leading natural philosophers of his time.

If we score Lamarck, Erasmus Darwin and Chambers 9 or 10 on a scale of 1-10 in the Progressionist stakes, then I suspect that Charles Darwin himself would score around 5. As always he was temperate in his comments, at least by the standards of his time, balancing one comment off with another. On one hand in the *Origin of Species* we find Darwin writing that: "as natural selection works solely by and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection". Progress for Darwin was a consequence of biotic competition. In crowded ecosystems full of competing life forms, the constant removal of inferior by superior life forms would impart a progressive direction to evolutionary change in the long run. But then Darwin writes in his letter to the American progressionist palaeontologist Alpheus Hyatt on Dec 4th 1872: "After long reflection I cannot avoid the conviction that no innate tendency to progressive development exists". And we find Darwin scribbling in the margins of a progressionist text: "Never say higher or lower".

Darwin's most enthusiastic supporters simply dispensed with his caution and propounded a robustly progressionist view of evolutionary history. Herbert Spencer, arguably the most famous philosopher of his age, had already started working out a great developmental Lamarckian scheme for the evolution of nearly everything in *Progress: Its Law and Cause* published in 1857 and simply absorbed bits of Darwinism into his scheme as they came along, but remained more Lamarckian than Darwinian for the rest of his life. In his *Social Statics*, Spencer proclaimed that "Progress, therefore, is not an accident, but a necessity. Instead of civilization being artificial, it is a part of nature; all of a piece with the development of the embryo or the unfolding of a flower" (Spencer 1851). Spencer maintained that the end point of the evolutionary process would be the creation of 'the perfect man in the perfect society' with human beings becoming completely adapted to social life. Darwin didn't use the word 'evolution' at all in the first edition of the *Origin* because it carried the sense of 'unfolding' with a strong connotation of inevitable progress, but Spencer pushed the word heavily and Darwin first starts using it in *The Descent of Man* in 1871.

Darwin's bulldog Thomas Henry Huxley was, unlike Spencer, a proper scientist, but was also a moderate progressionist, seeing evolution as the inexorable working out of natural laws, "a wider teleology which is not touched by the doctrine of Evolution" that "does not even come into contact with Theism, considered as a philosophical doctrine." But in later life we see Huxley reacting more strongly against progressionist views in his Romanes Lecture of 1893 entitled 'Evolution and Ethics' where he critiques the idea that there is any order or purpose in evolution, and so moral values should be developed in defiance of nature's laws.

Despite the caution of Huxley and indeed of Darwin himself, the progressionist tradition continues on unabated right through the 20th century, with evolutionary thinkers in the first half, such as T.H.Huxley's grandson Julian Huxley, and R.A.Fisher, together with the Catholic Lamarckian palaeontologist and theologian Teilhard de Chardin, in their very different ways keeping alive a progressionist stance. But as Michael Ruse points out, following the development of the neo-Darwinian synthesis in the 1920s and 30s, it now became much less respectable to talk about progression in scientific publications (Ruse 2010). Instead such material was relegated to the popular writings of the evolutionary biologists, as in Julian Huxley's hugely prolific output during the 1920s to 1950s, Huxley being attracted to vitalism and the writings of Henri Bergson.

Writing in the midst of the Second World War we find Julian Huxley extolling progress in the conclusion of his book *Evolution: the Modern Synthesis* (1942), but now tempered with the kind of realism that is rare in writers such as Spencer: "Evolution is a major fact of past evolution; but it is limited to a few selected stocks. It may continue in the future, but it is not inevitable; man, by now become the trustee of evolution, must work and plan if he is to achieve further progress for himself and so for life". So evolution passes on the baton of Progress to Man, who must keep up the good work. Top marks for optimism to someone publishing in 1942.

Many of the great evolutionary biologists of the latter half of the 20th century, such as Ernst Mayr and E.O.Wilson, were likewise convinced progressionists, Wilson writing that "Progress, then, is a property of the evolution of life as a whole by almost any intuitive standard, including the acquisition of goals and intentions in the behaviour of animals". Ernst Mayr said the following to Michael Ruse in a taped interview in 1993 towards the end of his very long life, for he lived to be 100 (and published his last paper when he was 100, an example to us all):
"In your treatment, about half the time you talk about Progressionism with a sneer, always illustrated with some detestable examples of racism or male chauvinism. I think much of your writing would be improved if you would admit that much of Progressionism was a rather noble philosophy. In fact a very good case could be made for the claim that the current mess is the result of the loss of this philosophy" (Ruse 2010).

Not until the writings of Stephen Jay Gould do we find a really vigorous all-out onslaught on progressionism, Gould proclaiming in 1989 that it is a "noxious, culturally embedded, untestable, non-operational, intractable idea that must be replaced if we wish to understand the patterns of history" (Gould 1988). So, he does seem to have been against it. According to Gould, we are a "momentary cosmic accident," albeit a "glorious accident." Summing up his view, Gould writes: "Wind back the tape of life to the early days of the Burgess Shale; let it play again from an identical starting point, and the chance becomes vanishingly small that anything like human intelligence would grace the replay".

And yet even Gould seems to have moderated his position in later life in *The Structure of Evolutionary Theory* published in 1992, the year of his death, and 1433 pages really does allow an author to add plenty of "ifs", "ands" and "buts". And so on page 468 we find Gould commenting: "But the history of life includes some manifestly directional properties – and we have never been satisfied with evolutionary theories that do not take this feature of life into account". And it turns out that the progressionist accounts that Gould liked to attack most heartily were, if not exactly windmills, then at least items that can leave other forms of progressionist narrative untouched.

No-one could judge Richard Dawkins to be less than enthusiastic about evolution, and he comes across as rather a strong progressionist in his 1997 review of Gould's book *Full House*: "progress to mean an increase, not in complexity, intelligence or some other anthropocentric value, but in the accumulating number of features contributing towards whatever adaptation the lineage in question exemplifies. By this definition, adaptive evolution is not just incidentally progressive, it is deeply, dyed-in-the wool, indispensably progressive".[1] And then in his *Ancestors Tale* we find Dawkins writing that "the cumulative build-up of complex adaptations like eyes, strongly suggests a version of progress — especially when coupled in imagination with some of the wonderful products of convergent evolution" (Dawkins 2004).

This sampling of progressionist and anti-progressionist narratives from the past few centuries makes one point clear: there is no over-arching 'grand narrative' that allows the philosophically inclined historian to categorise the various understandings of 'progress' into some neat classification system. Biology, and life, are too messy for that. Nevertheless it is equally clear that at one end of the spectrum of meanings lies biologists such as Dawkins who see 'progress' as defined within narrowly defined biological terms, entailing increased complexity associated with new adaptations, whereas at the other end lie the expansive visions of a Lamarck or a Julian Huxley, for whom the escalator of life is certainly moving towards something better, even though the delineation of the pot at the end of the rainbow remains rather ill-defined for these, as for other enthusiastic progressionists.

Evolutionary Progress and Christian Theology

This brief summary has at least reminded us of the immensely long and complex debate that has surrounded the whole issue of progression in the evolutionary literature and beyond. And the question I now wish to ask is whether the outcome of this discussion makes much difference to Christian theology.

The traditional Christian understanding of evolution, which starts with thinkers like Charles Kingsley and Frederick Temple as soon as the *Origin* is published, and continues in an unbroken lineage since that time, is that it represents the creative process that God uses to bring about his intentions and purposes for biological diversity in general and for humankind in particular. And the phrase 'humankind in particular' is referring to the fact that humans are made in God's image, with a particular relational function and role to play in the purposes of God, not least in the caring for God's earth. God, in initiating and sustaining this process, is not seen as the divine puppet-master, least of all the heavenly engineer who occasionally tinkers with the machinery, the picture conveyed by the proponents of Intelligent Design, but rather the God whose immanent faithfulness in guaranteeing the reproducible properties of matter likewise guarantees their propensity for life, the biological diversity which we as scientists then seek to describe and understand. Creation is about ontology, authorship, the fact that something exists rather than nothing.

Now I am not sure that this kind of theological narrative should commit Christians to any particular theory of progression in evolutionary biology, except in a rather weak sense discussed further below. We do not need to deny that prokaryotes such as bacteria remain the most abundant and in many ways most successful independent life-forms that have remained essentially the same for billions of years. We do not need to believe that every evolutionary lineage inevitably tends to develop in the direction of greater complexity. Many do. Many don't. Some degenerate and lose more complex items, like the eyes that get lost when animals go and live in caves, no longer necessary for their ecological niche. We certainly don't need to believe in any kind of *élan vital* that is impelling life-forms upwards and onwards to some future higher state. Instead we can happily accept that in evolutionary terms we are indeed one small twig on the evolutionary bush, and given that our lineage likely passed through one or more genetic bottle-necks of around twelve thousand inter-breeding individuals or less, realize that we might so easily not have been here. We can realize all of these things, and many more, but I am not so sure that they really make any difference to the theological narrative that I have out-lined.

Instead what we notice is that our twig does have some rather special properties. The evolutionary process has delivered beings with a kit of attributes that do in fact render the theological account both feasible and coherent. These beings have big frontal lobes that facilitate cogitation and moral decision-making. They have a basic moral tool-kit, which is quite possibly inherited in the same way that the neuronal machinery for learning languages is inherited. Their language, grammar and memory together generate the continuity and development of culture and of relationships. They have a religious sense, a cognitive bias perhaps to believe in God's agency. Many of these characteristics appear numerous times in evolutionary history – communication, culture, music, creativity, all in their various forms keep popping up all over the place in different evolutionary lineages, but it is in the particular package of these attributes within the human twig that we find located the possibility of a freely chosen relationship with God and real moral responsibilities. We just don't take animals or plants to court. And religion, to the best of our knowledge so far, does seem to be a unique property of this little twig. This is what, as a matter of fact, evolution has delivered, and certainly we can call this progressive in comparison with the far more numerous prokaryotes, but equally the recognition of the special qualities of our twig needn't make us deny the intrinsic value of all the other twigs on this wonderful bush. It's just that we actually *care* about the extinction of the other twigs, whereas they don't.

There is, however, a weaker sense in which we can label the evolutionary process as 'progressive'. Given the theological framework already introduced, that God fulfills his intentions and purposes through the evolutionary process, just as he does through the created order taken as a whole, we can, if we so wish, label the process as 'progressive' because it does, as a matter of fact, take us from a to b, from non-living matter to living matter through to thinking, feeling, morally choosing human-beings. Of course. How could God's world not fulfill God's purposes? But by engaging in such a definitional exercise, we are thereby, *ipso facto*, rather removing the language of 'progression' from the ways in which it has generally been used in an evolutionary context over the past two centuries. Questions of 'progress' and 'purpose' cannot be discussed in vacuo, as it were, as if one were starting the discussion with a blank slate. Whether it be Lamarck's great escalator of life, or Spencer's philosophy of the evolution of just about everything, with Chambers following in his train, or Huxley's conviction that evolution represented the inexorable working out of natural laws, or de Chardin's grand evolutionary narrative in which the whole process is heading towards the 'omega point', there seems no particular good reason why Christian theology should feel a need to incorporate biological evolution within such narratives of progress. In a contingent universe, God can bring about his intentions and purposes, which include the creation of humanity, any way that he chooses, and so there seems no good reason why it should occur by one way more than another. The contingency of the world entails that it would be unwise for Christians to hook their wagon to the latest progressionist narrative to emerge from evolutionary theory.

But if theology doesn't commit us to any particular theory of progression, except in the very general terms that I have out-lined, then it does act as a brake to a particular flowering of progressionism – the idea that humankind itself is progressing morally and even inevitably towards some future better state. This previously popular view was of course largely killed off by the horrors of the 20th century, although surprisingly the idea still crops up even today. Be that as it may, Christian theology simply points out, using the Fall narrative as a resource, that general moral progress is not an intrinsic capacity of human being on the earth, and that outside of redemption and grace there is little hope of genuine progress.

Is there Purpose in Evolution?

Now what about the other 'P' word hovering alongside Progression – 'Purpose'? It is quite possible to be an ardent progressionist in evolution, without believing that the process taken as a whole has any purpose in any ultimate sense. This is clearly the position of Richard Dawkins when he writes, perhaps on a rainy day in Oxford: "The universe we observe had precisely the properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind pitiless indifference." (Dawkins and Ward 1995).

The philosopher Daniel Dennett agrees – Dennett asks whether the complexity of biological diversity can "really be the outcome of nothing but a cascade of algorithmic processes feeding on chance? And if so, who designed that cascade?" Dennett answers his own rhetorical question by saying: "Nobody. It is itself the product of a blind, algorithmic process". "Evolution is not a process that was designed to produce us" (Dennett 1995).

The discussion here is not then about the question of progression as such, but about the question of purpose, the word that Dawkins uses. And here we do have to mark a parting of the ways. For clearly the idea of purpose is implicit in the kind of theological outline that I have introduced. The idea is that indeed the evolutionary process is fulfilling God's creative intentions and purposes. But on the other hand I rather agree with Dawkins and Dennett that if you look at the evolutionary process as an atheist and simply through the window of biology, then there is nothing there that *forces* upon you a narrative of ultimate purpose. Without the revelation of God in Christ there is no framework, no matrix, within which to place evolutionary history, to provide it with an overall purpose and coherence.

So does that leave advances in our understanding of evolution completely divorced from our theological understanding of purpose? Not completely. We certainly cannot in my view *derive* theology from the evolutionary process itself, though some have tried to do just that, but I do think that our current understanding of biology renders less plausible the suggestion that evolutionary history *necessarily* lacks any plan or purpose. Let me give seven examples of what I have in mind.

First, and most obviously, evolution taken as a whole is not a chance process. This at least is where atheists and theologians can sing from the same song sheet. As Dawkins writes in *The Blind Watchmaker*: "One of my tasks will be to destroy this eagerly believed myth that Darwinism is a theory of 'chance'" (Dawkins 1986). Of course the process incorporates chance in the generation of genomic variation, of course there are stochastic events leading to mass extinctions, but the winnowing effect of natural selection ensures that in the finely tuned interaction between chance and necessity it is necessity which wins in the end. So evolution is a highly organized and in many ways highly conservative process.

There is a certain irony in the reflection that the secular Thomas Henry Huxley was suspicious of the role of chance in generating variant phenotypes of organisms upon which natural selection then acted. For Huxley, chance sounded like an opening for God's special creation, whereas he wanted to see evolution as emerging out of natural scientific laws. The irony arises from the fact that in his day Huxley resisted the idea of chance, because he thought that it had theological overtones, whereas creationists today resist the idea of chance because they think that it has atheistic overtones. Often people interpret essentially the same data in quite different ways depending on their political, economic and cultural contexts. In any event, had Huxley been alive today he would most likely have been pleased with the tendency in contemporary evolutionary theory to highlight the law-like behaviour of the trends observed within the evolutionary process.

Secondly, stand back and look at the 3.8 billion years of evolution as a whole, and the striking increase in biological complexity is obvious. For the first 2.5 billion years of life on earth, living things only rarely got bigger than 1 millimetre across, about the size of a pin-head. There were no birds, no flowers, no animals on land, no fish in the sea, but at the genetic and cellular level there was considerable development and diversification, with the generation of many of the genes and biochemical systems that were later used to such effect to build the bigger, more interesting living things that we see all around us today. At the same time the oxygen levels in the atmosphere increased to the point at which more complex life-forms could be sustained.

It is not until the advent of multi-cellular life from around perhaps 1.2 billion years ago that living organisms start to get bigger, although even then they were generally on a scale of millimetres rather than centimetres. Only in the so-called 'Cambrian explosion' during the period 505-525 million years ago do we find sponges and algae growing up to 5-10 cm across, and the size of animals began to increase dramatically from that time onwards, until today we have creatures like ourselves with our brains with 10^{11} neurons with their 10^{14} synaptic connections or more, the most complex known entities in the universe.

As Sean Carroll from the University of Wisconson-Madison remarks in a *Nature* review: "Life's contingent history could be viewed as an argument against any direction or pattern in the course of evolution or the shape of life. But it is obvious that larger and more complex life forms have evolved from simple unicellular ancestors and that various innovations were necessary for the evolution of new means of living" (Carroll 2001).

Third, underlying biological complexity are networking principles that are turning out to be fewer and simpler than they might have been. Networking principles refer to those organizational systems that are used in all living organisms. Just as similar traffic control systems are used in all the world's cities, because there is only a limited array of methods that can be used for organizing traffic, so all cells in all organisms display a limited number of organizational motifs. Given that in every cell, complex networks of interactions occur between thousands of metabolites, proteins and DNA, this is quite surprising. As Uri Alon from the Weizmann Institute comments: "...Biological networks seem to be built, to a good approximation, from only a few types of patterns called network motifs"...."The same small set of network motifs, discovered in bacteria, have been found in gene-regulation networks across diverse organisms, including plants and animals. Evolution seems to have 'rediscovered' the same motifs again and again in different systems..." (Alon 2007).

We may link this to what Sean Carroll has called 'deep homology'. This means that if you look at complex organs in animals such as limbs and eyes, in many cases it's possible to track back their evolutionary histories to see how such structures arose by the modification of pre-existing genetic regulatory circuits, established very early in animal development.

Fourthly, the very limited array of protein structures used by living organisms compared to the astronomically huge number of possible structures is also very striking. Proteins are made up of a specified sequence of 20 different amino-acids and a single protein may contain hundreds of amino acids. Yet if you look at all the known proteins in the world, and their structural motifs, based on all the genomes that have been sequenced so far, you find that the great majority can be assigned to only around 1400 protein domain 'families'. In other words, all living things are united not only by having the same genetic code, but also by possessing an elegant and highly restricted set of protein structures.

Recent findings also suggest that proteins can only evolve along certain quite restricted pathways because of the internal constraints built into their own structures. For example a research group from Harvard published a paper entitled 'Darwinian evolution can follow only very few mutational paths to fitter proteins' (Weinreich et al. 2006). They studied an enzyme called β-lactamase which breaks down antibiotics such as penicillin. Provided that bacteria have versions of this enzyme that are functioning efficiently, they grow quite happily in media containing antibiotic. If a gene is under natural selection then it needs to evolve in small incremental steps, each step increasing the fitness of the organism or at least not decreasing it. There are five amino acids needed at five key positions in the sequence of amino acids that make up the β-lactamase enzyme that enable it to function well enough to enable the bacteria to grow in antibiotic. So by random events you could imagine the gene evolving to this state through five mutations that might occur in any order; in principle there could be 5x4x3x2 = 120 different mutational pathways to achieve the goal of optimal enzyme efficiency. But in practice the Harvard researchers found that 102 of these pathways are barred because they decrease the fitness of the bacteria, i.e. their ability to flourish in the presence of antibiotic, and of the remaining 18 trajectories only a very few were really favored. It is intriguing to read the authors' conclusion of their paper reporting this work: "We conclude that much protein evolution will be similarly constrained. This implies that the protein tape of life may be largely reproducible and even predictable".

The idea of 'fitness landscapes' can be quite useful for envisaging how evolution occurs at the molecular level. These traditionally represent topographical pictures of the adaptation of different populations to local ecological niches, visualised in the same way that three-dimensional models can be used to give a good idea of mountainous areas like the Swiss Alps. The peaks represent those areas of 'optimal fitness' at which a population is well-adapted to its particular environment.

The concept of 'fitness landscapes' can also be applied to enzyme structure and function. Again and again it turns out that the evolutionary pathways to arrive at a particular function of a particular enzyme are remarkably constrained. In other words, there are only a few ways to arrive at a particular protein function because only some genetic mutations will get you there and not others. It is as if an evolutionary path is laid out in front of the gene encoding the enzyme, and the genetic dice keeps being thrown until the enzyme structure is generated that optimises fitness for its particular function. This is no random process, each step along the way being preserved by benefits to the organism that uses the enzyme. In a recent review on this approach to investigating the evolution of protein functions, the authors conclude: 'That only a few paths are favored also implies that evolution might be more reproducible than is commonly perceived, or even be predictable' (Poelwijk et al. 2007).

Overall it appears that around 98% of all the amino acids in all proteins cannot change because of the striking decrease in fitness of the organism that would result (Povolotskaya and Kondrashov 2010). This means that the genes that encode these amino acids cannot change either, at least not by mutations that change the amino acid sequence. This might sound like a recipe for a static protein world. In practice this is not the case: proteins do evolve, but they just do so really slowly and cautiously. For example, if other random mutations occur in the same protein, then the constraint on the 98% of 'frozen' amino acids is lifted somewhat. It's unlikely that the evolutionary search engine has yet completed its job of searching the complete repertoire of protein 'design space', but it has come a long way in 3.8 billion years, and the present 'snapshot' that we have certainly points to a highly constrained molecular world. In practice what this means is that if a random jumble of amino acid sequences is generated, the vast majority (indeed an astronomically huge number) will have no function at all, and it is up to the evolutionary search engine to find the tiny number that have functions useful for life.

Fifthly, as with proteins, so with genes, there are underlying biological principles that constrain the location and type of gene evolution. The 'raw material' for evolution is provided by 'random' mutations, gene flow and the genetic recombination that occurs during the generation of the germ-line cells. But note that 'randomness' here means only that genetic variation occurs without the needs of the organism in mind. By contrast the genetic variation that leads to evolution is not 'random' in the sense that any kind of variation in any kind of gene will do. In reality there are so-called "hotspot genes", those that are far more likely than others to play key roles in evolutionary change, such as a gene that delights in the name *shavenbaby* found in the *Drosophila* fruit-fly. Such genes act as 'input/output genes', encoding key switching proteins that integrate whole sets of information that are then mediated to downstream effectors. The *shavenbaby* gene regulates the existence and distribution of fine trichomes or cellular hairs on the surface of the larvae of *Drosophila*, so that mutations in *shavenbaby* lead to a lack of trichomes – hence the name (Stern and Orgogozo 2008, 2009).

It is genes such as *shavenbaby*, "hotspot genes", that render evolution possible because they regulate an integrated programme of events, in this case converting cells into hair-making cells. The mutations that occur are in the regulatory sequences of this gene that control how much of the protein is actually made. So far about 350 of these kinds of "hot-spot genes" have been identified in plants and animals. As the authors of a recent review entitled 'Is Genetic Evolution Predictable?' comment: "Recent observations indicate that all genes are not equal in the eyes of evolution. Evolutionarily relevant mutations tend to accumulate in hotspot genes and at specific positions within genes. Genetic evolution is constrained by gene function, the structure of genetic networks, and population biology. The genetic basis of evolution may be predictable to some extent….." (Stern and Orgogozo 2008).

Sixthly, there is the remarkable phenomenon of convergence, the repeated evolution in independent biological lineages of the same biochemical pathway, or organ or structure, to which writers such as Dawkins and the Cambridge palaeobiologist Simon Conway Morris have drawn repeated attention. In his fine book *Life's Solution – Inevitable Humans in a Lonely universe*, Prof. Morris brings together hundreds of examples of convergence in evolutionary history (Conway Morris 2003). For example, the convergence of mimicry of insects and spiders to an ant morphology has evolved at least 70 times independently. The technique of retaining the egg in the mother prior to a live birth is thought to have evolved separately about 100 times amongst lizards and snakes alone. Compound and camera eyes taken together have evolved more than twenty different times during the course of evolution. If you live in a planet of light and darkness, then you need eyes – so that is precisely what will emerge as the adaptive requirement arises. The hedgehog tenrecs of Madagascar were long thought to be close relatives of 'true' hedgehogs, because their respective morphologies are so similar, but it is now realized that they belong to two quite separate evolutionary lineages and have 'converged' independently upon the same adaptive solutions, complete with spikes. Hundreds of other examples of evolutionary convergence may be found at this web-site: www.mapoflife.org.

Evolutionary convergence at the phenotypic level does not mean that a complete set of new genes evolves separately each time to build, for example, an eye. Far from it. Genomes contain genes that may be switched off, ready for use at some future time as required, or genes that presently have quite different functions, which can be pressed into service. There are many examples of genes that encode 'moonlighting proteins' – proteins that carry out quite different tasks depending on whether they are inside the cell or outside, on the particular tissue in which they are located, or even on which specific location they occupy inside a cell (Jeffery 1999).

There are many examples illustrating the way in which convergence to generate similar adaptations operate at the molecular level. Echolocation is the method that mammals such as bats, porpoises and dolphins, use for hearing. It involves sending out pings of sound that bounce off objects and are then received back and analysed – an animal sonar system, used not just to detect the presence of objects, but to locate and identify prey. The brain works out how long it takes for the ping of sound to come back, and so how far away is the object. Bats can detect the presence of a tiny crawling insect or even a human hair, and can recognize each others' 'voices'.

A special protein called prestin is key to this sophisticated highspeed process (Jones 2010). The gene that encodes this protein is unique to mammals and has evolved independently several times since mammals split off from the birds in evolutionary history more than 100 million years ago. Prestin is found in the outer hair cells of the inner ear of the mammalian cochlea, a fluid-filled chamber. As the fluid is compressed by the sound waves the ear receives, so the sensory hairs surrounding the chamber move very slightly and convert their movements into nerve impulses via thousands of 'hair cells'. The outer hair cells that serve as an amplifier in the inner ear refine the sensitivity and frequency selectivity of the mechanical vibrations of the cochlea.

The specialized prestin found in echolocating mammals provides a much faster system for converting air pressure waves into nerve impulses than the prestin found in mammals (like us) that do not use echolocation. The convergent story became apparent when it was discovered that the prestin gene has accumulated many of the same mutational changes in bats, porpoises and dolphins, changes that are essential for prestin to perform its unique functions (Jones 2010). Similar changes have occurred in unrelated lineages of different bats. Genetic evidence suggests that these changes have undergone natural selection. In other words, here is an adaptation that is of great advantage to the animal that has it, so animals carrying this particular set of mutations in the prestin gene are more likely to reproduce and spread the beneficial gene around an interbreeding population. The particular advantage may well be the necessity to hear very high frequencies, far above the ability of the human ear to hear. The advantage of possessing this specialised piece of echolocation equipment has helped shape the evolution of the prestin gene such that it has converged on the same adaptive solution independently on multiple occasions.

In a commentary on Gould's idea of contingency, Prof. Conway Morris writes that: "[I]t is now widely thought that the history of life is little more than a contingent muddle punctuated by disastrous mass extinctions that in spelling the doom of one group so open the doors of opportunity to some other mob of lucky-chancers. ...Rerun the tape of the history of life... and the end result will be an utterly different biosphere. Most notably there will be nothing remotely like a human...Yet, what we know of evolution suggests the exact reverse: convergence is ubiquitous and the constraints of life make the emergence of the various biological properties [e.g. intelligence] very probable, if not inevitable" (Conway Morris 2003).

So indeed the rolling of the genetic dice is a wonderful way of generating both novelty and diversity, but at the same time it appears to be restrained by necessity to a relatively limited number of living entities that can flourish in particular ecological niches. If you live in a universe with this kind of physics and chemistry, and on a planet with these particular properties, then the biological diversity that we do in fact observe is what is most likely to emerge. Evolution is a search engine for exploring design space. Biological diversity is definitely not a case of "anything can happen". Only some things can happen, not in a deterministic way, but in a highly constrained way.

The seventh example that highlights the highly organized nature of the evolutionary process relates to the emergence of the human mind. Only a very ordered and constrained process could produce something as elegant and complex as the human mind. Personhood developed in evolution with increased self-awareness and what we now call a 'theory of mind', in turn dependent upon the rapid increase in brain size that has taken place in the hominin lineage. In this understanding, mind is an emergent phenomenon, meaning that something with totally new properties has emerged which cannot be adequately understood or described using the language of biology.

Only two million years ago did hominin brain size begin to seriously surpass that of our nearest living cousin, the chimpanzee, which has a brain volume of about 400 cubic centimetres. Bipedality does not appear to be the critical factor that has driven this rapid cultural evolution, for certainly the hominins (most likely *Australopithecus* *afarensis*) who left their fossilised footprints in the volcanic ash at Laetoli in Tanzania, 3.5 million years ago, were bipedal, but the first stone tools do not start appearing until 2.6 million years ago, so bipedalism and tool use may be necessary but not sufficient to explain the rapid brain evolution that occurred later. A more likely explanation is the increasing complexity of hominin social life over the past two million years, in which the need for cooperativity in hunting and other social activities gave significant evolutionary advantages to those with larger brains.

Increasing bran size was characterized by an increase in the numbers of 'orders of intentionality' (Dunbar 2004). The idea of 'orders of intentionality' comes from the 'theory of mind', the ability of our own minds to realise that there are other minds that think like ours and that have intentions and purposes that may be similar or even quite different to ours. We take this 'mind-reading' completely for granted but it is in fact a crucial aspect of our identity as humans. To engage in communal religious beliefs, for example, several different orders of intentionality are required, in fact four and perhaps as many as five. In an example given by Robin Dunbar, with each level of intentionality underlined and numbered: 'I <u>suppose</u> [1] that you <u>think</u> [2] that I <u>believe</u> [3] that there is a God who <u>intends</u> [4] to influence our futures because He understands our <u>desires</u> [5]'. Dunbar speculates that 4th order intentionality would not have appeared until about 500,000 years ago, about the time of the emergence of archaic *H. sapiens*, with 5th order intentionality appearing with anatomically modern humans around 200,000 years ago, perhaps along with language.

A comment from Martin Nowak, professor at Harvard University, is striking in this context. Nowak has published much recently on the mathematics of game theory in the evolution of social cooperation. Nowak comments (in 2009): "My position is very simple. Evolution has led to a human brain that can gain access to a Platonic world of forms and ideas" (https://cogito.cty.jhu.edu/17754/does-evolution-explain-human-nature-2/. Accessed May 29, 2013.)

Might it be scientifically feasible to link up all these seven examples (and more) in some larger theory that might show how the constraints imposed upon matter by the laws of physics and chemistry in a planet with these particular properties lead inevitably to the kind of biological systems that we in fact observe? In principle there seems to be no good reason why such a 'grand theory' might not eventually prove possible, although in practice we are presently very far from such a scenario. But recent advances mean that asking the question does not seem quite as silly as it might have done only a few decades ago.

Even with our present rather limited understanding, if we reflect on just these seven examples of order and constraint in evolutionary history, it is clear that far from looking stochastic and random, evolution looks highly organised and constrained – predictable to some extent, perhaps even with inevitable outcomes. Note that I am not suggesting that if we read the evolutionary narrative just as biology that *therefore* evolutionary history per se displays some ultimate purpose, but rather a more modest claim, that these kinds of data – and many more – render the claim that evolutionary history is necessarily a purposeless history less plausible. In science it is often data that count *against* a theory that are the most powerful, as Karl Popper was fond of reminding us, and it is the biological data in this case which count against the idea that evolutionary history is a purposeless random walk without rhyme or reason. In human experience, narratives that are highly ordered and constrained are not normally without some kind of purpose.

Of course there are other types of argument that have been mounted against the idea that evolutionary history is consistent with a God who has intentions and purposes in bringing such a history into being. For example, it took too long, or it was too wasteful, or it involved so much death and suffering. The first two objections are rather trivial; the third is weighty, but space does not allow to address these further questions here. I have addressed them elsewhere (Alexander 2008, 2011), and the problem of animal suffering in evolution has likewise been addressed extensively by others (Southgate 2008)(Murray 2008).

We can conclude with the kind of comments that we frequently make in the Discussion section of our scientific papers – the data are *consistent with* our favourite model, whatever that happens to be at the time. In like manner this highly organized and constrained evolutionary history is *consistent with* the theological claim that there is a God who has intentions and purposes for the world in general and for us in particular. Evolutionary history fits comfortably within the overall matrix of a theistic universe in which God wills that carbon-based intelligent life-forms emerge (us) who have the ability to respond freely (or not) to His love for us. And the fact that we are sitting on a very small twig in the great bush of evolutionary history should act as a reminder that we are only here by God's grace, and also that his grace extends to our future prospects as well.

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When we went to see the End of the World

Malcolm Drummond

Introduction

'When we went to see the end of the world' is a short story by Robert Silverberg, first published in 1972. In the story, a group of decadent twenty- and thirty-somethings meet for one of their regular parties and discuss their recent holidays. It turns out they have all taken the same trip, a new (very expensive) expedition in a time machine to see the end of the world.

As they discuss their experiences they realise that although they all paid for the same holiday, they all witnessed quite different things. They saw:

- The death of the last living creature, a crab-like thing crawling across an empty beach.
- The last mountain crumbling into the sea.
- The whole planet coated in its own frozen atmosphere.
- The sun going nova.
- The moon breaking apart, its fragments falling to earth in a great storm of giant meteorites.

The first chapter of 'The End of the World and the Ends of God' (edited by John Polkinghorne and Michael Walker) is by W R Stoeger and is called 'Scientific Accounts of Ultimate Catastrophes in our Life-Bearing Universe.' It introduces other possibilities, including the very distant future decline of the universe towards a state of 'heat death,' where not only all living things have died, but matter itself has decayed into an expanding cloud of low-grade radiation.

Which is the real 'end of the world,' or 'end of the cosmos'? Or are all of them in their own ways endings worthy of the name? And what about the 'end' of the universe in the sense of 'what it is for, its chief purpose'?

These are obviously different questions. Science is neither atheistic nor theistic. It is by its very nature agnostic. To misquote Alastair Campbell, 'science doesn't do God.' It is the scientists, not the science itself, who decide whether to be a Dawkins or a Polkinghorne, and the decision has to be made on grounds other than scientific.

Letting the Text Speak

As Christians committed to developing a Biblical outlook, we have an interest not only in what science anticipates as the future 'end of the world,' but also in what our faith has to say on the same subject. We surely want to be as radically Biblical as we can, and that means challenging our accepted understandings of the Bible if the Bible itself requires us to do so from signs in the text itself and from improved exegesis. We do not do this so that we can accommodate the Bible to other things, whether science or current cultural shifts, tempting though this is.

The relationship between the Book of Genesis and the geological and biological sciences has been dealt with from every possible point of view and every possible conclusion has been reached. The debate is well summarised in Denis Alexander's book, 'Creation or Evolution: do we have to choose?' I know from experience that for many evangelical Christians the answer is 'yes, we do.' For the more atheistically inclined, the answer is equal and opposite. I happen to agree with Denis' conclusions, in the main, because they are reached not despite the Biblical witness but because of it, seeking to treat the text as the text itself demands to be treated.

With Genesis, for most of our history we took it as a reasonably straight-forward, if metaphorical, description of what actually happened when God made the heavens and the earth. What choice did we have? Now, on the one hand, we have other ancient texts which, while they do not have priority for us over the text of Scripture, do nevertheless cast clear and relevant light on Genesis; and on the other hand, the findings of geology and evolutionary biology. We have had, if we follow Denis and others, to rethink Genesis – not to avoid the clash with science, but to be faithful to what the text was always saying, even if we did not have the necessary knowledge available to us before.

Something similar to the process of Biblical, theological and scientific thinking that is summarised in Denis' book needs to be done equally thoroughly for the Last Things of Christian eschatology.

Which End? Which World?

When the Bible speaks of the end of the world (or *cosmos*), to what is it referring? What are we to make of Judgment, the Second Coming, the General Resurrection, or the New Heavens and the New Earth, in the light of current scientific thinking, let alone the Rapture, the Tribulation, or any of the other aspects which mean so much to so many? How, if at all, does this thinking relate to our understanding of the various 'ends' science anticipates for our species, our planet, our star and our cosmos?

What happens if we take the process we followed with Genesis and both cosmic and human origins, and do the same thing with Eschatology in general, and Apocalyptic in particular?

In What Sense Does the Cosmos Have a Purpose?

Can a 'thing' even have a purpose? It is not a quantifiable property. If such a purpose exists, does it arise from the essential nature of the thing itself, or from someone's perception or appreciation of the thing? Does a galaxy, as a galaxy, have a purpose? Do electrons? The creation does not groan as in the pains of childbirth (Romans 8:22) – *we* groan over its bondage to decay, and we hope for a new heaven and a new earth. The creation will be set free into *our* freedom (Rom. 8:21). It seems that statements about purpose or meaning or goals have at their heart the assumption that these things arise within the observer reflecting on the world. Perhaps this is even part of what we mean by being made in the image of God, because ultimately meaning and purpose derive from the Creator if they exist at all, and we are reimagining God's thoughts after him. God did not become an electron or a galaxy, but a human being, full of grace and truth.

This property of the cosmos may not be measurable, but that is hardly a problem. A lot of interesting things cannot be quantified, usually because they are in the brain of the beholder. The answer to the question 'How beautiful is my wife?' is 'But soft, what light through yonder window breaks? It is the east, and Linda is the dawn,' and emphatically *not* '0.16 Juliets.' With some interesting properties of the world, to quantify them is to spoil them. Our perceptions – our brains – are such a part of the thing being measured that it doesn't exist at all without us. A thing can have mass and extension of itself, but not beauty.

In the Discworld novel 'Moving Pictures,' Terry Pratchett describes a device invented by a previous professor at the Unseen University called Riktor (p. 100):

> The Archchancellor tapped the pot with his knuckles. 'What, old "Numbers" Riktor? Same fella?'
> 'Apparently, Archchancellor.'
> 'Total madman. Thought you could measure everythin'. Not just lengths and weights and that kind of stuff, but everythin'. "If it exists," he said, "you ought to be able to measure it."' Ridcully's eyes misted with memory. 'Made all

> kinds of weird widgets. Reckoned you could measure truth and beauty and dreams and stuff. So this is one of old Riktor's toys, is it? Wonder what it measured?'
>
> ...
>
> That afternoon a couple of porters moved the universe's only working resograph into the Archchancellor's study. (Resograph: a device for measuring disturbances in the fabric of reality).

Mathematical entities exist, if that's the right word for their mode of being, regardless of whether or not we are here to discover and enjoy them. They have that Platonic side to them. Art, music, beauty – these things exist only in the enjoyment of them. Without us they are empty of meaning. Physics, it seems to me, occupies the borderlands between the two – observational but real, right on the edge between objective and subjective, with mathematics as the metaphorical language we use to describe the cosmos we can observe and measure.

Unmixing our Metaphors

All abstract language is essentially metaphorical (in the sense used in linguistics). Without metaphor we have no way to speak about beauty, love, art or music. All theological language is consequently also metaphorical. Whenever we use language to link the incommensurate, moving from what we experience directly to what is beyond our immediate sense impressions, we are speaking metaphorically, and God is surely incommensurate with us in this sense. The revealed nature of theological discourse serves to make this meaning-filled gulf more, rather than less, stark.

This distinction between the metaphorical landscapes of physics and theology is analogous to the traditional ideas of first and second causes. Science is agnostic and recognises no first cause, but tends towards reductionism as a result. Second causes are a complete and consistent explanation of causality (this is the essential justification of the entire scientific project), but they have nothing to say about questions of significance, meaning or purpose. It is not even possible to ask the question within that way of thinking. A scientific explanation of love or art or beauty tends to be astonishingly unsatisfying, fundamentally disconnected from the experience itself and therefore missing the point entirely.

Theological thinking embraces second causes as part of a description of how the world works, but prefers thinking about the First Cause, understood not as the start of all following causation, but as the hidden but significant underlying cause of all second causes. It is the difference between event-time and significance-time or filled-time. The two appear poles apart, but this is an illusion. Science is a source of wonder; theology is one of the sciences of the unquantifiable faces of reality. Both are true, and both are interesting (in the sense of not being trivial). Both are built from metaphor.

Metaphor links incommensurate things – that is its point. Both theology and science are metaphors of reality – one experimental and general; the other experiential and particular. This complementarity enables them to keep each other in check.

The metaphorical nature of theological discourse has always been recognised. Calvin called it God's condescension to speak to us in terms we can understand, like lisping to a baby. In metaphor, we start from things we know from our own experience to find descriptions for things that are beyond that. The additional step we take in theological thinking is to reverse the abstraction. For example, we love our children. To understand how God relates to us, we call him Father, the One who loves us as we love our children. But to avoid this being an intrinsically unstable extrapolation – God is like us, only bigger – we take the conclusion and make that the premise. God's love is the real love; ours is derived from his. All families take their true name from him, rather than the reverse. We are like him, but dependent on him. This gives a strongly monotheistic foundation to our thinking. God is Subject, not object, and ultimately everything derives from him. Whether this revelation comes directly or by the providential selection of particularly clear forms of definitively monotheistic thinking makes no difference because these are two different ways of saying the same thing – top down and bottom up, like the difference in the approach to Christology between the Synoptics and the Fourth Gospel. Top-down and bottom-up theology both reach the opposite terminus in the end.

Scientifically the end of the world – especially the end of the human world – could come in any one of a dozen clearly quantifiable ways. Theologically, the end is going to be something that is not measurable in that way, but is focused more on hope and the transformation of life in love.

Some Hope

Although in the Bible this eschatological hope extends to the animal kingdom and indeed to the whole created order, the primary focus is on mankind's response to the coming of God and God's gracious response to our need for him to come – so much so that the animal and cosmic dimensions of that hope could easily be seen as extrapolations, universalising analogies of the transformation to come along the lines mentioned above.

Perhaps we can go one step further, and say that the cosmic transformation is more a transformation of our perception of or involvement with the cosmos as part of that cosmos than a change in the cosmos itself.

When Christ returns, should we expect to see a change in the fundamental constants, or perhaps in the very laws of physics? The Scriptures can certainly be read in this way, and Rodney Holder expressed the view at the Symposium that in the new heavens and the new earth the second law of thermodynamics would no longer apply. If in the future universe the rules have been changed, we are unable to make scientific statements about it at all other than those revealed in Scripture (Dr Holder's comment being based on Rom. 8:21f). Yet we have no reason to think that they changed at the Fall, the Incarnation, the Cross, the Resurrection or the Ascension. As a thought-experiment, may we ask what shape Christian eschatology would take if in the renewed universe, as far as science is concerned, it was business as usual?

What form will this renewal have taken in that case? What will have changed? What changed with all the other things? Nothing? Or everything? The universe changed when I became a Christian, in that I changed, and seeing the cosmos in a new and vibrant way was part of that change.

> Heaven above is softer blue,
> Earth around is sweeter green;
> Something lives in every hue
> Christless eyes have never seen:
> Birds with gladder songs o'erflow,
> Flow'rs with deeper beauties shine,
> Since I know, as now I know,
> I am his, and he is mine.
>
> (From 'Loved with an Everlasting Love,' by George Wade Robinson).

This is not something that could be measured, but it is no less real.

From this point of view we are not necessarily talking about any of the physical ends of the world, but more of a transition from humanity as it now is to humanity as it will be, realising the longing to walk with God in the cool of the evening, to know as we are known.

It's the End, Jim, but not as we know it

According to the New Testament the great theological truths have always been true ('the Lamb of God, slain from the foundation of the world' in Rev. 13:8 for example). They have the nature not of time*less*ness but of time*ful*ness, becoming instantiated in time, in the progressive way which is the only way we have of engaging with it, at particular points in our history. If these theological events were always the case but became historical at a particular moment for us, something similar could be true for the Consummation, the return of Christ and the remaking of all things.

Even if these things deal more with the human perception and interaction with creation than with any essential change in creation itself, what will they look like? Here we are, as N T Wright puts it, looking at a signpost pointing into a shining fog. The signpost is true, but it is only the sign, not the substance. Metaphor is the only language we have for something so utterly beyond us.

I think we need a similar process to the one followed with Genesis and cosmology. We need to be as careful as we can to identify and interpret the genres of the texts correctly. We need some idea of what worldview they are undermining from a monotheistic, or Trinitarian, perspective. And we need to remember that the scientific description is itself open to revision, but from new experimental evidence and analysis, not theological or Biblical critique.

With apocalyptic literature we struggle to understand partly because we do not know enough about the metaphorical background to the text. We are like Captain Picard in the *Star Trek: The Next Generation* episode 'Darmok.' The Tamarians' language is impossible to understand, because although the words make sense – they are all names of people or places – they are drawn from ancient stories which are unknown to the Captain. Instead of saying "Let us overcome our differences and become friends by facing a common enemy," the Tamarian captain repeatedly says, "Darmok and Jalad at Tanagra." Without knowing the stories behind the metaphors, the Tamarian language remains incomprehensible. To an extent we struggle to understand apocalyptic for similar reasons.

Above all, we need to find a theology of endings (and new beginnings) that is honest to the understanding of the Bible that the form and history demand, and which deepens without undermining our scientific understanding of the ultimate death of everything.

Death and Resurrection

When thinking about life and death and hope, as Christians we naturally turn to the Resurrection, of Christ as the first-fruits, and then of all people. We also think about the remaking of the heavens and the earth and the coming down of the New Jerusalem and the lion lying down with the lamb, but I have already given reasons for seeing these as rhetorically hyperbolic extensions of our future human experience of God.

Whatever approach we might take to miracles (and C S Lewis' idea that they represent not so much exceptions to the laws of physics as changes in the boundary conditions upon which these laws act does rather appeal to me), in the Resurrection of the Son of Man we have one of those time*ful* events which was always true but which was realised at a particular time and place in our history. In the New Testament this event is not unique in itself, but only in its priority. It anticipates resurrection as God's general response to death in the fullness of time, and generalises it to the entire suffering, decaying cosmos.

In the discussion of the resurrected body of Jesus in the Gospels and Acts, and our own future resurrected bodies in 1 Corinthians 15, we see both continuity and change. Continuity of the conscious identity of the individual, but change and transformation to be fitted for a new and different kind of existence in a new and different kind of cosmos. If we experiment with the idea that the cosmic change is not in the cosmos itself but in our perception and experience of it as people fully reconciled to God, the key element in the transformation is a renewal of humanity in God. Jesus had emptied himself in the Incarnation, and was re-filled as Crucified and Risen. In our own death and resurrection, or transformation in God, we who were always empty are filled in him.

The Bible makes the general resurrection universal and simultaneous, at least in most peoples' reading of it. This makes it a species-wide event, like a mass extinction in reverse. How we unravel the metaphors will vary from person to person, but I can see two main ways forward here.

Firstly, a sort of evolutionary step, along the same lines as the one Denis argues for the first self-revelation of God to our ancient ancestors. When our brains and our linguistic ability reached a critical point, God first began to lisp to our infant ears in ways we could start to understand. Perhaps there is more than one step in that process. Now that our evolution appears to be largely in the world of ideas rather than biology, perhaps another such step is on its way. If this all sounds rather 'Age of Aquarius,' Stephen Pinker argues in 'The Better Angels of our Nature' that for all of recorded human history we have been becoming less violent, less bloodthirsty and less cruel, and that this process does not seem to be slowing down. I didn't believe it either, but he makes a very persuasive case!

The other possibility is that the general resurrection is the other side of the coin of a literal mass extinction. If we believe in the resurrection of Christ and the future resurrection of the dead, why not the resurrection of a species? Perhaps the coming of Christ is another way of looking at our transformation in him through death to a new kind of life on the other side of the end of our species as we currently know it. One of the characteristics of Apocalyptic, after all, is a strong reversal of events between their perception by humanity and their perception in the heavenly realm. We are persecuted to death; we win the victor's crown.

Conclusion

The bitter irony of Silverberg's short story is that throughout the narrative current events keep interrupting, and it becomes obvious that the reason none of them saw the end of mankind as one of the possible future ends of the world is that they are themselves witnessing the end of mankind right now without even realising it. At the end of the story the protagonist's wife says she wants to go and see the end of the world all over again, and he laughs quite a good deal. Were we in his shoes, we would pray a good deal, and look up to heaven. As Augustine said, 'We are an Easter people, and hallelujah is our song!'

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Book Reviews

Robert J.Asher *Evolution and Belief:Confessions of a Religious Paleontologist*
Cambridge Cambridge University Press 2012 300pp. £15.99 ISBN 978.0.521.119383.2

In the Prologue to this book, Asher introduces us to his personal belief in God and his profession as a palaeontologist. It becomes clear that he particularly wishes to help those who feel their worldview is threatened by evolution. As he puts it, 'I want you, the public, to understand that evolutionary biology' does not explain everything and does not rule out religious belief (xxiii).

A more formal discussion of science and religion begins in chapter one. A key point that Asher makes here is the need to distinguish between what he calls 'agency and cause'(6). He acknowledges that this corresponds closely with the centuries-old distinction between primary and secondary causation. And what makes the current debate over evolution and creation so frustrating for him is that both creationists and atheists usually fail to make any such distinction. Chapter two then introduces the science of evolution, emphasising how the scientific search for natural causes is a practical method and not a dogma. Asher also explains clearly why Intelligent Design is not science, drawing on philosophy and theology as well as biology. In a later chapter on biology and probability he is quite scathing about the attempts of ID proponents to make a case for 'irreducible complexity', describing their efforts as 'patently false' and 'fundamentally misleading' (215, 216).

The core of this book is chapters three to ten, where the author gives an excellent account of the study of evolution. His focus is on the quest to work out the pattern of animal ancestry, which is often summarised in diagrams called evolutionary trees or cladograms. Asher naturally gives much attention to the fossil record, especially those parts where the record has been enriched by new fossil finds in recent decades. These include the evolution of mammals from mammal-like reptiles, especially their ear bones, and the evolution of whales from land-dwelling mammals. Asher concludes his account of the fossil record by taking on 'the anti-evolution crowd' in a chapter titled 'Creationism: the Fossils Still Say No!' (140). This chapter includes a table that fills six pages listing fossil animals that show intermediate features, contrary to creationist claims.

Asher then devotes a couple of chapters to the rapidly expanding study of DNA in relation to evolution. He shows how this has both confirmed and revised earlier conclusions drawn from the study of fossils. A nice example is the finding that the same genes control the development of the ear bones in mammals and the bones of the jaw joint in reptiles. This is exactly what one would expect if the former have evolved from the latter as the fossil record suggests.

Overall this book has two aspects, which present something of a contrast. One is the author's wish to reach out to the wider public. This results in a text peppered with the words 'you' and 'your', which can come across as a bit condescending. Moreover, parts of the text and many of the diagrams are too complex to be easily understood by someone with no background in biology.

The other aspect is the author's account of the factual basis of evolution and of the ongoing research in this area. Here his expertise and enthusiasm shine through and a wide range of appropriate science is well explained. Sources of this material are meticulously cited in extensive endnotes and there is a good bibliography. So this book can be highly recommended as a valuable resource for those who would like an insight into evolutionary biology and its relevance to current debates.

Reviewed by Dr.David Young

Rodney Holder *Big Bang, Big God:A universe Designed for Life?* Oxford Lion Hudson 2013 208pp. pb.£8.99 ISBN978.0.7459.5626.8

When Stephen Hawking wrote his best-selling book *A Brief History of Time* in 1988 there was an optimistic feeling that a grand unified theory of science was just around the corner that would explain the universe and everything without the need for God. In this, his latest book, Rodney Holder has demonstrated that such optimism was mistaken. The book starts in 1915 with Einstein's theory of general relativity and traces the history of rival theories about the origin of the universe focussing particularly on Georges Lemaître and Fred Hoyle. The author shows that these two, with others, championed respectively the Big Bang and the Steady State theories of origin. The two men were very different. Lemaître was a Roman Catholic priest who had a preference for a spatially finite universe but did not allow his theology to determine his science. He criticised Pope Pius XII, who believed that the Big Bang theory supported the doctrine of creation, for having confused creation, which is inaccessible to science with origination. Hoyle, along with Gold and Bondi, favoured the Steady State or Continuous Creation theory because they felt that religion was based on dogma and was unscientific and people turn to it to give the universe and themselves a significance they do not have. The evidence to support this theory was hard to find and Hoyle became engaged in a bitter dispute over this with Martin Ryle. The author agreed that Hoyle lacked humility and had a reputation for being an entertainer (he had once said that it is better to be interesting and wrong than boring and right), but was nevertheless a great scientist. Ironically Hoyle, commenting on the apparent fine-tuning of the universe suggested, 'a super-intellect has monkeyed with physics'! Eventually the Big Bang theory won with the day with confirmation of a predicted cosmic radiation, the remnants of the initial explosion, being confirmed by Penzias and Wilson in 1965.

Holder then turns to the question of whether the universe had a beginning and looks at the issue from both science and religion. Stephen Hawking and colleagues, while accepting the Big Bang theory, argued that in the earliest moments space-time 'smoothed out' and time became a dimension of space and this four dimensional universe had no boundary or edge and therefore no singularity and no need to appeal to a creator. Holder asks how did the universe evolve from this 4D state? More recently Hawking has appealed to a radical interpretation of quantum physics, as did Hoyle, by which we create the past by our measurements and observation. Also M or string theory predicts that a great many universes were created out of nothing and that negative gravitational energy cancelled out positive matter energy. But surely there must have been something to be observed ? If this speculative theory is to be accepted is it not better to follow the philosopher George Berkeley that the universe exists because it is observed by the eternal God rather than paradoxically that it comes into existence retrospectively by later human observation? Turning to the Christian faith, the author points out that from the earliest centuries Christian apologists have maintained that the universe was not created in time but time was created with the universe. The universe is contingent upon God, who alone is necessary (needs no explanation). The universe was created out of nothing and is totally dependent on God for its continual existence. Attempts to redefine nothing in terms of a quantum vacuum is compared by Holder with the king in 'Through the Looking Glass' wishing that he could see Nobody as Alice claimed to do when she said she saw nobody on the road. The Christian view has the advantage of explaining why there is something rather than nothing in existence.

Dr. Holder then turns to the issue of fine-tuning. Our universe seems to be specially designed to ultimately produce embodied self-conscious agents (ourselves). He describes a dozen examples of fine-tuning out of a much larger number. These include the size of the universe, the mean density of matter and energy, the initial entropy, the initial conditions for the production of hydrogen and water, the right kind of stars to produce the heavier elements needed for life and the strength of gravity. Such fine-tuning needs explanation and it is not enough to say that because we are here then the conditions must have been right and the constants could not have taken other than the values they do. In successive aptly named chapters ('Of the Making of Many Universes there is no End' and 'Multiple Problems of Multiverses') the author describes and criticises various attempts to explain fine- tuning without resorting to an intelligent creator. He evaluates theories of oscillating universes, inflation theories and those arising from interpretations of quantum physics such as the many worlds and M (string) theories. He argues that multiverse theories are speculative and too complex, whereas the theistic view more conforms with the basic scientific principle of Ockham's Razor that we should not multiply entities needlessly. In addition a multiverse would not solve the problem because it would itself need to be finely tuned.

He concludes the study by comparing the explanations proposed by the scientists discussed in previous chapters with those offered by Christian theism and finds the latter wins. Contrary to what scientists like Paul Davies and Richard Dawkins maintain, traditionally God has been considered a simple being not made up of parts. God is a necessary being, that is if God exists He is not dependent of anything or anyone else for his existence and exists of necessity. The universe, by contrast, is dependent on something or someone and is therefore contingent and need not exist. Equally there is a good reason for a personal God to create a universe in which rational creatures can exist and enjoy a relationship with Him. Rodney Holder concludes by appealing to scientists not to abandon observation and experiment in their metaphysical quest and to acknowledge that Christian faith is not credulity but 'faith seeking understanding.'

The book is comprehensive and the author uses his expertise in both physics and theology to good effect. The book is written in non-technical language with mathematical equations restricted to an appendix on Bayes' theorem. The subject matter is often difficult for the general reader to comprehend and I fear that the reader with little or no scientific background, even with the use of the provided glossary, will struggle and be tempted to give up. This would be a pity for this volume provides the reader with a comprehensive defence of both science and the Christian belief in God as Creator.

Reviewed by Reg. Luhman

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