



Overview

Professor Andrew Briggs delivered a lecture on `Nanotechnology – Grey goo or great God?` on Thursday 10th March 2005 in the Octagon Theatre, St Catharine's College, Cambridge. An audio recording of the lecture and questions along with a transcript of the lecture in pdf and HTML format is available at:

<http://www.st-edmunds.cam.ac.uk/cis>

The lecture was subsequently followed by a dinner/discussion with the speaker at St Edmunds College, Cambridge. An edited transcript of this discussion follows. It was chaired by Prof. Bob White (Department of Earth Science, University of Cambridge) with introductory remarks by Prof. Colin Humphreys (Materials Science, University of Cambridge). The other contributors are described at the end of the discussion.

Templeton Foundation Post-dinner Discussion

Andrew Briggs – 10th March 2005

Bob White: As you know, there's no such thing as a free lunch and there's also no such thing as a free dinner! Colin has very kindly offered to start us off with some thoughts and then it would be great if we can have an objective of everybody contributing something. We have fifty-five minutes left now, which means that you have to be fairly succinct, and maybe two or three people could make their points and then ask Andrew to respond to them.

Colin Humphreys: I would like to start by saying how much I enjoyed Andrew's talk. I thought it was a masterful talk, very stimulating, beautifully put together, and he gave us spectacular images, both stills and movies: I think it's the first time we've had clips from films in one of these lectures. The audience was really good despite the competition which, in fact, was fiercer than Andrew said: not only did he have competition from the Archbishop of Canterbury and from Alec Broers giving a Reith lecture, but actually there was another competitor as well, a Nobel prizewinner giving one of the Scott Lectures in the Cavendish at the same time. So there was tremendous competition this evening and yet Andrew brought together and attracted this audience.

Now to move to the issues which affect science and religion. The first one Andrew mentioned was the argument from design. He mentioned William Paley and the well known example where Paley supposedly found a watch on the seashore and, after picking it up and marvelling at the design, concluded that such an intricate work had to have a designer. That, I think, is a well known story. It comes from intelligent design and Andrew emphasised some of the examples that the intelligent design people are using as nanoscale examples, for example that there are biological organisms which have nanoscale motors and nanoscale gear wheels rotating

nanoscale flagellae. They are remarkable and it is difficult to explain – difficult, but not maybe impossible. Nanotechnology raises some issues on intelligent design.

Then there are safety issues which were just touched upon, so I think that we might want to return to that with some of our questions regarding safety issues about nanoparticles, whether these are really dangerous in principle, and whether these are the sorts of things we need to take great care about.

Then at the end of his talk, Andrew homed in on the physical nature of information and he quoted John Chapter 1, v. 14 “The word became flesh” or in the original Greek “The word flesh became” and mentioned the whole concept here of the abstract becoming physical. He then quoted David Deutsch talking about looking at the nano level where we find information stored in a complex and remarkable way in quantum form. Andrew ended by saying that developments in nanotechnology will raise in new forms questions about the creator.

I would like to ask the first question on this subject of the physical nature of information and ask Andrew whether he thinks all information is physical in nature, and particularly information about God. Then if we come to man, the older ideas were that man had a tripartite nature, what he saw as the spirit and moving on to dualism; and now many people believe in monism. In all these man is a central unity and this physical nature of information, tied up with the idea of man being the central unity and maybe looking at life after death where the Bible emphasises a bodily resurrection – is this again somehow tied up with the fact that human information needs to be stored in a physical sort of form? So those are the questions I would like to start by asking Andrew.

Andrew Briggs: Thanks Colin. As usual, you have asked the questions that make one really think, so I hope that if we do go away this evening even more confused than before, it will at least be at a deeper level!

Let me take the bit at the end about the unity of man. The writer who opened my eyes to this was Basil Atkinson who was here at Cambridge. He very much wanted to be a Cambridge don but never received a college fellowship and I think he went on to be number two in the Cambridge University Library. He started to write a commentary on the entire Bible but the commentary that he wrote on Genesis was so boring that he was persuaded to stop! He wrote a book called *Life and Immortality* where he went through, in his characteristic painstaking way, the uses of the Hebrew *nephesh*. He showed that you could not regard soul as a component of a person but that a soul *is* the person. Perhaps the most accurate use we get of it in the English language is when we say such and such a ship sank and so many souls perished. Another way of saying it is that a person is a soul and that impinges on two of the things that you mentioned. A particular point that he was making was that immortality is not a property of the soul, as the Greeks might have said, but that it was a *gift* that could be bestowed on a soul in response to faith. If that is true it has profound implications for almost every branch of ethics.

When Norman Anderson wrote his book *Issues of Life and Death* he was looking at ethical issues from the earliest moment of life to the last, from conception to dying. He was a person who was supremely qualified to do this because he and his wife lost all three of their children in adult life through a different cause in each case. He said that you can't address issues of ethics until you first of all say what you believe happens to a soul after death. The position that he adopted was consistent with what Basil Atkinson had said, which was that eternal life is a gift that is bestowed in response to faith – and the alternative to that for a person who does not have faith is exact and just and fair punishment followed by annihilation and destruction. Then you begin to have a sort of model that I think that you can communicate, though it

takes a certain amount of courage to do so. So that may impinge on your questions about eternal life.

Now as far as information goes this is something I'm wrestling with and trying to think through myself, but I think this kind of monist approach has to be the one that will prove fruitful. It certainly has proved useful in the science and technology of quantum information, which will enable you to do things you cannot do with classical information. It has led to the explosive growth of research in the area which is becoming more exciting by the week, so that we can scarcely open a copy of *Science* or *Nature* without, if not in every issue then at least in every other issue, reading of some breakthrough in quantum information. I think I'm still trying to find out what the merits of thinking of information as physical are and I would love to hear the views of people this evening.

The slogan "information is physical" is one that has launched a thousand research projects. Landauer's paper of that title expounds a kind of anti-platonic viewpoint. I would love to get views of people around the table as to what the limitations and the applicability and usefulness are of perceiving the physical nature of what we might otherwise think of as abstract concepts.

Malcolm Guite: Could I offer to reverse the slogan "information is physical" and restore Plato by saying "physicality is information". Might it be the case that if we recognise the necessary physicality of our information, and I'm really interested in the ideas of resurrection of the body and what is the spiritual, but might we put it the other way and consider reductivism. Scientists, particularly in biology, are interested in this and actually say if it is the case that we recognise now that the things that we think of as values, truths, beauties, meanings, that are embodied in our information, have a physical base, we might look at all these other things which have been described as "merely" or "reductively" physical as actually being Logos, being word, being language, containing and embodying and communicating truth. Is that a possibility?

Bob White: Would anyone else like to follow up on that?

Hyung Choi: I have a problem with the words in combination with physical. My question is what do you mean by physical, what is matter and what is a thing? So if you really go into this quantum work and description of what we used to call "physical" it's very hard now to say what physical really is. When we equate, when we say our information is physical, are we not saying something deeper than both what we used to call information which used to be kind of mental, and what we call physical, which used to be part of mental work. We are actually pointing to a deeper reality and I'm just wondering if the paradigm may change our whole dichotomy, like mental and physical, if it may point to deeper unity.

Chiranjib Mitra: Information in the present day computer is coded in a physical form. If you delete some information, which is an irreversible process, then some energy is dissipated. I'm sure Andrew can explain that in more detail. So that's macro energy conversion, which is perfectly conservative.

Bob White: Surely, when you delete information on a computer disk you are just replacing some information which may be ordered and meaningful with different information, which may be random or meaningless, but nevertheless contains just as many bits or digital numbers.

Chiranjib Mitra: If you delete, which is an irreversible process, it's a dissipating process.

Mike Payne: I think it is right to point to the influence of David Deutsch in understanding quantum information and quantum computing in its present day context, but Feynman appreciated the basic ideas of a quantum computer back in 1959. The thing that Feynman didn't overcome, and what David Deutsch did, was a

change in the paradigm of how these computers work. There are several insights but the most important insight is that if you want to actually get something useful out of a quantum computer, don't expect it to work every time. If you use the model of a classical computer and apply it to quantum computation you gain nothing; you have to shift the paradigm to say "Well, let's accept that it only works half the time and we will run it several times until we find the right answer".

To some extent I differ perhaps in my attitude and I think it's partly because I don't understand information theory but *why* quantum computers are powerful is really nothing to do with information, it's to do with quantum mechanics and the way that quantum mechanical systems evolved; that was what Feynman appreciated. What he *didn't* understand, and that's what David Deutsch needed to do, was to change the model of how to access that information but the processing ability was understood way before Deutsch came into the scene.

Information theory is odd because if you take a random series of zeros and ones – we've talked about the zeros and ones in computers – in information theory that is exactly the same as either half of the data set being zero and the next half being one, or it being a pattern of 010101: the Shannon entropy of those distributions is exactly the same. Information theory at the level of the Shannon entropy is no different between those three sets and yet you look at them as a human and you realise that two of them have a huge amount of organisation and the third doesn't.

Bob White: So, Andrew, having heard those comments perhaps you can address them. I think the point that Malcolm made is well taken. It has often been said that science tells you how things work and it's only by revelation from God that you can see why things are the way they are, why we are here in the first place. That's really what Francis Bacon said, that you need the Book of Nature and the Book of Revelation to understand the world in which we find ourselves. But if beauty can be explained in a physical way, as well as a table being explained in a physical way, it may bring a different perspective to Francis Bacon's comment. Was Francis Bacon wrong with his view of the universe or not, particularly when you take ideas about information being physical?

Andrew Briggs: Well, let me take a different approach – which is really a way of saying these questions are much too hard! – and ask the question how in the Bible is knowledge of the natural and creative world related to faith? Rather than going straight to the early chapters of Genesis, which is probably a rather difficult place to start, maybe a better place to begin is with some of the prophets who talk about creation and are explicit about *why* they are talking about creation. An example of that would be in the middle of Isaiah, say Isaiah Chapters 40–55, where quite a lot is said about creation and quite a lot is said about *why* the prophet is talking about creation. That section in Isaiah is encouraging people to faith, to do something which on the face of it seems pretty scary. The prophet says, "Clear a road through the desert for the Lord." My guess is that the people to whom this was addressed were being encouraged to embark on a new venture that had rather painful associations. Various arguments are adduced to address various fears, and one of the fears was that God was incompetent, not really in control. I suppose that the reason that that one had arisen very naturally was that at the time the best god was the god that gave you a military victory, just as now in certain circumstances the best god is the god who gives you prosperity, or lots of scientific publications, among other things. Earlier in Isaiah when Ahaz singularly failed to listen to Isaiah's advice in the face of the Syro-Ephraimite alliance, he had been warned in no uncertain terms that God was going to demonstrate his power by letting them all be led into captivity, which was completely unprecedented in the Israelite history or indeed in the Ancient Near East. The evidence from the stars and the created world itself was given not to change atheists into believing God, but to encourage believers to have faith and confidence in the God

who actually they already knew from their experience, and from their worshiping community, and from the scriptures.

It's perhaps not too big a step from that to go then and look at Genesis Chapter 1 and Chapter 2 up to the first half of verse 4, which seems to have been put at the beginning of the Bible as a preface to what was going to follow, to say that the God who you're going to read about in the following pages is exactly and precisely the same as the God who created the whole show. So you get to those throwaway lines such as "He made the stars also", which would have been particularly poignant in a society where the Babylonian gods seemed to be so supreme. So now I hoped that I've talked for long enough for you to have forgotten what the question was!

Bob White: I would like to open up the discussion a little to address the issue of the ethics of nanotechnology research. Whenever scientists do something new there are always some people who say, or at least who consciously or subconsciously think that "because we can do it, we should do it". But there is obviously a counter argument that maybe we shouldn't pursue some particular avenue of research if there are large risks associated with it. Alan talked a little bit about the risks after the lecture, but I wonder if we might amplify this aspect, particularly from a Christian perspective. Is nanotechnology a good thing to sink resources into, when the person down the road will say that there are fifty million people starving in Africa, so shouldn't we spend some money on them? Furthermore, there's the issue that maybe we are making something that's highly carcinogenic, that's potentially very dangerous, so is that a good idea or not? What are the benefits compared to the risk? Does anybody have any comments on that perspective, on the ethical perspective of doing this sort of science with nanotechnology?

Alan Windle: I think it was Charles Frank who said that physics is essentially an activity of the mind. I don't think we can control activities of the mind and I don't think they need much funding. I think there will always be a quest for new understanding, whether it's quantum entanglement or something much more mundane. If we are saying we can't really control that and shouldn't, then the whole thing gets reduced to a much more basic level, to what experiments should we do and what are the risks. Perhaps we could do all our experiments in computational modelling so then we wouldn't have as much risk - other than getting backache!

I think I'm concerned that the ethics of health are actually slightly mundane compared with the real issues around this table. We can talk about it, we've talked a bit about it this afternoon, and there's an aspect of that which is being as responsible as one can on the Christian ethics side. I think that the amazing thing about this conversation is that thirty years into it I don't think we've mentioned a nanomind. I think that's very important because of the actual issues nanotechnology is just another example: there is nuclear power, we had GM technology that went wrong because of lots of issues. These things come, the mind is questing forward and nothing will stop that. The way you do experiments is indeed an issue for us to be concerned with but I don't think that the quest for knowledge and understanding will be quenched.

Bob White: What about the cost of doing nanotechnology research, is this a good use of our resources?

Alan Windle: I don't think that that's the right way to answer the question but if I try and develop that you can simply see me as a cynic. Money is simply society deciding where it wants to put faith as interpreted by politicians and if it wants to put faith into nano fine, we'll all join.

Bob White: Well is it fine, though, that's the question?

Alan Windle: I'm sorry, by "fine" I mean you must read that in a much more cynical way and I'm not sure you would interpret it that way because you're a nice guy. I think

that just watching the way money is moved around, and the factors that really determine how it's moved around, makes you much more concerned about the political process than anything to do with science. The question as to whether we should spend money on nanotechnology is a very simplistic entry into what is very complicated and is to do with man's quest for power and control and the way, whether it's politics or industry, it works. It's very funny, actually, that Andrew showed those films of the poor academic (if he was), facing up to his sponsors, as I actually came straight from a meeting of my sponsors in nanotechnology – they were actually very much nicer than the ones on the film, I have to add – but they were asking the same sort of questions, should they invest three million pounds in a new plant - and saying to me “You don't know yet, do you?”. I had to say “No we don't, but you're in the risk game, that's why you're wealthy” (if they are). It's a different world. I'm not saying it's a particularly spiritually enabling world, but it's a real world of power out there, of money, of people feeling they are important, so I think there are many, many issues locked into that and I'm describing a fallen society, fallen humanity.

I think it's much more helpful to address the issues with which we started of information and how that affects our faith. I hope she'll forgive me for saying this, but Rachel's first question which she asked this afternoon is, I think, very deep in terms of whether we accept evolution and do we say “Yippee” at it, because the way Rachel expressed it is to me touching very close to spiritual values. You asked me about ethical issues and I'm saying yes I'll talk about them if you want me to, I'll try to answer questions that I'm sure we've all wrestled with not just me, please, but we're touching on very much bigger issues than the spiritual-physical interface which Colin mentioned in the introduction and I just hope that we can somehow grab one and I suggested one way of grabbing it.

Derek Burke: I was going to agree with that. Just to comment on the money, I heard on the news this evening that the government is raising the minimum charge for prescriptions by three pence and it's raising £400 million – that for us is a huge amount of money so at the macro national budget level money is a secondary issue and we have to lobby for money but we must be not persuaded by it.

I also wanted to say that I think there are much less clear ethical issues here than there are in some areas of biology where in reproductive biology, say, we are throwing them up constantly, such as new issues about taking bone marrow cells from siblings for designer babies, which was in the papers just this week. You are lucky actually, Alan, that the issues you face are less troubling ethically. Certainly I would want to say there are some things that we as scientists should not do because they are actually ethically out of bounds. I don't think in nanotechnology you are in that area, you're in the risk area, but I agree with you too that that's rather mundane. We could talk about regulation but let's go back to what you people started with which I found fascinating, but only partially understood, which is the nature of information.

Rachel Oliver: Could I add a brief caveat? I would really love to talk about the nature of God in creation for ages, but another thing that's important to me in my faith is that both the gospels and actually the Old Testament have, to a surprising extent, an awful lot to say about social justice. The amount of £400 million raised by putting three pence on a prescription charge would save an awful lot of lives in Africa, as well as funding an awful lot of science. You can't have much of a discussion beyond “Oh yes, you could save a lot of lives in Africa” but for me as a Christian it's not something I can ever dismiss, just how blessed I am to live the life I live, in the first world, doing interesting science that I really enjoy, living in a comfortable house (and eating very nice dinners!). But the ethical issue of what the money *isn't* doing is in some ways profound because these are children who do not grow up, and I don't really have a lot further to add because there isn't much to add. We are dealing with political reality

and I have marched in London to tell the government they ought to do something about this, and it had little effect. It is actually a profound and a painful question.

Nicole van der Laak: I don't know how we want the discussion to evolve, but perhaps one of the things we could think about is whether money will be spent because, for example, not all scientists are Christian and the reality is that people are curious and will want to investigate things that intrigue them. So perhaps one of our roles as people who wish essentially to make good out of what we do is to consider these issues of whether and how money should be spent and what are the boundaries – to try to establish some rules and regulations. Of course it's not going to be liked by everyone because it never is, but perhaps our role is to establish some ground rules on how the money can be spent because it *will* be spent, whether we like it or not – and that's an idea to consider. Maybe that's our responsibility as well.

Bob White: Thanks, Nicole. Now I'm going to ask Denis if he wants to respond from the biological point of view to what Colin mentioned at the beginning of the discussion, that nanotechnology equates to small things and the case for irreducible complexities in small things.

Denis Alexander: May I just make an ethical comment arising from Nicole's comments? I have spent quite a lot of my career overseas using what was, in those days (early 1980's), deemed to be fairly high tech genetic technologies to help the developing world in a medical context (human genetics). One of the ethical challenges faced was: "how could we give so much high-tech stuff to a certain segment of the population when a lot of low-tech stuff would help a much larger proportion of the population?" I think that question is always a tension in development work in any country.

The position I've come to over the years is a fairly pragmatic one, and it's what I call the 'spill-over' position. A lot of new technologies are developed, for obvious reasons, in affluent countries that can afford the development costs. At first such technologies are restricted to those countries, but quite quickly get exported as companies look for new markets – the technologies start 'spilling over' into other parts of the world. Likewise when the new technologies are introduced into another country, at the beginning a relatively small number of people benefit. But as the economy (hopefully) strengthens, then there is a 'spill-over' effect whereby more and more people start to gain access, particularly as new technologies often get cheaper as they mature. I suspect that this may apply to nanotechnology as much as to genetic engineering. A good example is the way in which some countries have leapt straight into mobile phones without the need to go through the 'intermediate stage' of land lines. So personally I have a very positive view towards positive new technologies in terms of helping developing countries, because in the end the 'spill-over' effect will work out, although it may take some time. This is not at all an argument for not putting more money into 'low-tech' technologies – far from it – but instead an argument for not opposing the export of new 'high tech' technologies where they seem to meet a real need in a particular country.

Malcolm Guite: I should like to mention something going back to what are the deepest issues here. I was just reflecting again on Professor Briggs' talk. I was really interested in your exposition on Isaiah and I was asking myself what were the scriptural centres of your talk and I felt there were two of them. It's curious that there was the Genesis "made in the image" reference and your sense of image's responsibility, which is directly relevant to this question about money, and there was the John Chapter 1, v.14, "The word was made flesh". It struck me that, scripturally speaking, both of those are classical points because of the connection between the cosmic truth about the ultimate events of the cosmos and God and the particular truth of being human. In the Genesis case we're told that the link between the ultimate

truth of how things actually are and the particularity of our being human, is to be understood in this word image which you actually talked about in Hebrew. Then in the John reference we're told that ultimate truth, as it were.

I don't know if I can say this as a kind of nanotechnology from God's point of view, that that ultimate thing is made very particular in individuals in the tinyness of our system and it's like a divine take on a fantastic voyage. But ultimately I'm just interested in that reflection because I think your talk on the nanotechnology part of it has somehow expressed for me something which is a big, big theological thing: the relationship between the individual truth as we perceive it as human beings and the final truth of God.

I would want to say that the thing that prevented me from being a Christian, going through all models of atheists and agnostics and so on, I was an agnostic (or an ignoramus, as Benjamin Jowett said) because I questioned how could people who live as tiny creatures, perhaps an epiphenomenon of something else, on a little corner of the cosmos, even begin to have an idea about what is the case. That was the basis of my atheism. The change came from the notion of revelation that the truth behind things, the Logos, the basis of what might be the case, might have made itself manifest in the particularities of my personal situation. I'm just trying to feel my way towards it, but I think there may be some relation between your macro-micro scientific realm and what struck me as a macro-micro theological realm, that they're coherent in some way. I can't put it more than that.

Mike Payne: Well, while you're thinking .. ! This is something we're quite familiar with in science. If you look at where particle physics is going, they are going to energy scales which are totally unapproachable, but the hope is that what is happening at these very high energy scales will have sort of ripples that can be measured at the scales that we can access. This is precisely what you are saying. There is something that we can't access but somehow it's made some ripples within a scientific discipline that is precisely where they are at – they can't go to the ultimate of what they would like to prove but what they are looking at is orders of magnitude less, some sort of faint glimmer of what the truth is within their field, is precisely what you're saying.

Malcolm Guite: I think there's a feeling of reincarnation going on in the midst of all this.

Rachel Oliver: Does that make us ripples of who God is?

Mike Payne: Well I think our problem is, and we see this in Judaism, we should not question what God is. It's not for us to say "Oh you did that, and you did that, and that was really clever!" You know, it's ridiculous for us to sit round the table and say "Oh yes, we understand what he did". We are missing the fundamental point of God! And when Job started questioning God, then God rebuked him, quite correctly.

Malcolm Guite: But God also showed himself to Job, just to give, speaking theologically, a Christological reading of Job. I think the wonderful thing about Job is that all the discursive rational thinking answers to Job's problems are wrong, and Job says "Before I heard with the hearing of my ear, but now I see" and we're never told what he sees.

My personal feeling as a Christian is that the only thing that God could possibly have shown to Job that would have even begun to answer his suffering was God himself on the cross, and that would have been some kind of answer. So I would say my faith, such as it is, is based entirely on the notion that I can reason sufficiently to come to the end of my reason and confess my ignorance of God. I can't reason beyond that. But given the possibility of a revelation from the macro to the micro, in my scale, and my accepting the revelation of the word made flesh in Christ even as a

possibility, I can then begin to reason from that and say that yes, this begins to make sense of the complexity.

Andrew Briggs: I find this prompting from Job rather helpful. It happened that Diana and I were discussing some of this in Norfolk in November and we read a book by a person some of you here may know, Christopher Ash, who used to live near Cambridge. He particularly picks up this mention of Leviathan. Christopher throughout his book has been emphasising that there are lots of things that we as the reader know that Job didn't know. There's a remarkable passage where the Leviathan is described, which *The Revised English Bible* translates as a whale, and Job is asked if he will take him home to tea with his daughters. 'Don't even think about it!' advises God. If you try to take him on single handed, you won't forget the battle, and you won't want to do it again. If we can pull that together with what's been going on earlier in Job, part of what the book of Job shows is that there are spiritual realities which, if you don't take them into account, leave you completely unable to make any sense of the experience that he was going through. Once you do know that they're going on then it gives it a bit more sense and you won't try to take these things on on your own.

The relationship of that to what I was trying to probe with this physical nature of information question, without giving any glib answers and also without overselling the concept and pretending it's going to go further than it will, is that I sense that as scientists who have faith it is for us a greater challenge and a greater responsibility to work out what exactly we mean by, in traditional terms, the incarnation, or to try to put it into modern terms, that God participates in the physical world that is amenable to analysis by the mathematical and physical and biological sciences. They are remarkably successful and we use them in our laboratories with a measure of confidence. What does it mean for us to accept that a God to whom we can pray and who reveals himself to us is fully involved and fully participating in this material world in which we find ourselves and in which we have to live.

Hyung Choi: Your comment just now was related to what we talked about just before this meeting. As scientists we understand this natural world in terms of this natural world and it is very effective. When you really think of where the natural world comes from, where this incredible regularity comes from, as a creation I think we can relate it to God's involvement with this world. The incarnation itself, the very basis of the fact that we have a world which is really reliable in some sense seems to me to do with faithfulness of God. The character of the creator himself and his deed not only created but we often forget is the sustainer, a kind of continuing creation, the very basis of the natural is to do with his very involvement, it seems to me.

Denis Alexander: I think it's also helpful to reflect how much of God's creative activity described in the Bible is couched in very personal terms. For example, God speaks all the time in Genesis Ch 1, then speaks again in John Ch 1 and Jesus speaks when he's doing the 'creation miracles' in the Gospels (Matt. 8:27: The men were amazed and asked, "What kind of man is this? Even the winds and the waves obey him!"). There is a lot of theological speculation about how exactly God interacts with the world, but I find it intriguing that the Biblical emphasis is on God's creative actions by speaking, an example of what we might call 'top-down causation'. We may then view God's interaction with the world as an 'on-going conversation' (theism), not just an initial command that gets the whole show on the road (deism).

Andrew Briggs: God not being active after the initial creation would correspond to the Deist assertion of no revelation and God not speaking.

Ian McCaig: Just to follow on from what Dennis was saying, I think you raised a very interesting point earlier on which is God speaking to us and also about the short-term against the long-term, whatever the long term may mean. In terms of the work

that you do when you lift your eyes, what do you see? When you look to the future and God speaks to you and I presume, as we all do, you ask questions about what you do, and when we're talking about grey goo and nanotechnology and everything else, what do you see and what do you hear, whether it's three steps forward or four steps forward?

Andrew Briggs: Do you mean what's my vision for the science?

Ian McCaig: What's your vision for the science and how you relate that to your relationship with God?

Andrew Briggs: There are two things I am trying to do. One is to demonstrate entanglement between two solid state qubits. The other one is to achieve the transfer of quantum information between a static qubit and a propagating qubit. The BHAG (big hairy audacious goal) will be to turn these concepts in quantum information into a practical reality. Now if you say how does that differ from what a scientist who is not a believer would do, the answer might, at least in the short term, be probably not very much. The extra dimension for me, apart from all the ethical and relational issues that I guess we all face whatever scientific field we are working in, is how we can get a handle on this relationship between the concepts of quantum information and the concepts of what we experience as a physical. I would love to understand that better, I would love to see how it helps me to see perhaps a new parable, without claiming too much, to elucidate the relationship between God and his world that's encapsulated in the sort of things I was putting up on the screen

Ian McCaig: A new parable's not a small thing!

Andrew Briggs: I don't want to claim too much, though.

Bob White: I'm conscious that it's almost ten when we aim to stop. Does anyone else who hasn't spoken wish to say something?

Alex Weber: I just wanted to say a few words on something that's probably obvious to everyone here but from my experience at work and talking with scientists, I feel these questions we've been debating are very important and I think many people will struggle with them and find them very hard to reconcile with having faith. But I think it mirrors a little bit the macro to micro in that we really need to be very clear that it's not only our philosophical and theological explanation and reasoning that will win people to put their trust in Christ, but our being the image and showing Christ to people in our personal witness. So I think as much as these questions are really important to think about, and we need to give answers to them, and it would be foolish to say we can't answer this or we haven't thought about this just to bring a little impetus back. Personal responsibility as well is that we seem to be witnesses in the way we show love to others and I think there are many opportunities in life, I find that every day in which we can do that. They might not involve very much reasoning in a practical way - this is a just a little comment.

Bob White: It is ten so we should call this to a close. Do feel free to stay on and chat for as long as you like. Thank you everyone for your contributions and especially to Andrew for his work tonight.

Professor Andrew Briggs is Professor of Nanomaterials and Director of Quantum Information Processing Interdisciplinary Research Collaboration at the University of Oxford. He is an Honorary Fellow of the Royal Microscopical Society and past winner of the Holliday Prize, Institute of Materials, and the Metrology award for World Class Manufacturing.

Dr Diana Briggs was formerly a molecular and cell biologist and is on the committee of Christians in Science.

Dr Denis Alexander is a Fellow of St. Edmund's College and Chairman of the Molecular Immunology Programme, The Babraham Institute; Editor of the journal *Science & Christian Belief* and writes/lectures on science and faith; author of *Rebuilding the Matrix* (Lion).

Professor Derek Burke, former Vice-Chancellor of the University of East Anglia is a former Chairman of the Advisory Committee on Novel Foods and Processes and a former Specialist Adviser to the House of Commons Science and Technology Committee.

Professor Hyung Choi, Physicist from Arizona, Visiting Fellow at St Edmund's, writing a book on science and religion, supported by Templeton Foundation

Rev Dr Geoffrey Cook, Vice-Master St. Edmund's College; Department of Anatomy, research in developmental neurobiology.

Mr Russ Coxon graduated from Oxford University in 2001 with a degree in Engineering and Computing Science; since then worked in the marine leisure industry, including time spent developing satellite navigation and radar systems for small boats. Lives in Cambridge, is married to Katherine, a solicitor, and for the last two years has managed a sea school on the Suffolk coast.

Revd Dr Malcolm Guite is Chaplain of Girton College and a Senior Associate of the Cambridge Theological Federation. He worked on the Theology Through the Arts Project and is now pursuing an interest in the parallel development of dialogue between religion and science.

Professor Colin Humphreys is the Goldsmiths' Professor of Materials Science at Cambridge University, Professor of Experimental Physics at the Royal Institution in London and a Fellow of Selwyn College Cambridge. He is also the Director of the Rolls Royce University Technology Centre at Cambridge on Ni-base superalloys for turbine blades for aerospace engines, and the Director of the Cambridge Gallium Nitride Centre. He became the President of the Institute of Materials in January 2002. Prof. Humphreys has written and lectured widely on the subject of science and religion and his latest book is *The Miracles of Exodus: a Scientist Reveals the Extraordinary Natural Causes Underlying the Biblical Miracles* (Harper Collins, 2003).

Dr Ian McCaig Ian McCaig is Chief Operating Officer and an Executive Director of lastminute.com, Europe's largest independent travel/leisure website with over £1bn in transactions in 2004 and employing c2000 staff. Previously Ian spent 8 years in telecomms, most recently as a global Vice President of Nokia, and managed the introduction of their first commercial 3G networks. Prior to this Ian was in the IT industry for 7 years. He has a BSc Hons in Electronics & Electrical Engineering from Edinburgh University and is a Fellow of the BCS. Ian lives in Cambridge with his wife Lindsey and 5-month old daughter Flora

Dr Chiranjib Mitra is a Research Fellow in the Physics Department at University College London. He is working in the broad area of Nanotechnology and his specialised research is in the field of Quantum Computation.

Dr Rachel Oliver is a Research Fellow at Peterhouse College, Cambridge. Her research interests include the growth and characterisation of self-assembled nanostructures and the examination of the nanoscale electrical properties of materials using scanning probe microscopy.

Prof Mike Payne holds the Chair of Computational Physics, University of Cambridge. Has worked on first principles total energy calculations since 1985 and is the author of the first principles total energy pseudopotential code CASTEP. He was awarded the 1996 Maxwell Medal and Prize by the Institute of Physics and gave the 1998 Mott Lecture. He was the 23rd most highly cited Physical Scientist in the UK 1990-1999 with 2,869 citations (Institute for Scientific Information) and has published over 200 papers.

Dr Paul Shellard, Fellow of Trinity College; Dept. of Applied Mathematics and Theoretical Physics; cosmologist working on the early universe.

Nicole van der Laak is a PhD student in the Materials Science and Metallurgy department working on quantum dots, one aspect of nanotechnology.

Dr Alex Weber is in the Dept. of Biochemistry working on Toll-like receptors and their potential for therapeutic purposes; publicity organiser of science-religion lecture series.

Professor Bob White FRS, Fellow of St. Edmund's College; Dept. Earth Sciences. Leads a research group investigating crustal structure of the Earth, earthquakes and volcanoes. Co-author with Denis Alexander of *Beyond Belief: Science, Faith and Ethical Challenges* (Lion, 2004).

Professor Alan Windle FRS, Professor of Materials Science with a background in Polymer Science. Current interests include nano-based materials, application of Materials Science to biology and medicine, and virtual materials.



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