

God, Darwin and Design

CiS – Faraday Public Lecture given by Prof. Ken Miller on 28th April 2009

Good. Well it is my great privilege to welcome this evening Professor Ken Miller, who is a professor of Cell Biology at Brown University in the USA and as you may have gathered Professor Miller has been very involved in science education, in general biology and education in particular over these past years. Indeed was just telling me that his biology textbooks for undergraduates have sold four million copies, which is not bad. So if you were in an undergraduate in the states, especially in other parts of the world then his name is probably very familiar to swotting for biology exams and all that sort of thing.

Last year Professor Miller received the AAAS Public Understanding of Science and Technology Award in recognition of his work in communicating evolutionary science in North America. He has also been involved in the science religion discussion and we have a couple of Professor Miller's books on the books tool. Perhaps the best known is Finding Darwin's God, which is now in its 28th printing – I gather it has sold 100,000 copies. So it is doing well, but we have still got some more copies there for sale and I do recommend that, it really is a very, very good book on this whole topic.

Professor Miller has also been quite prominent over these past few years in being a major critic of the intelligent design movement in the United States and we will be hearing more about that I am sure this evening. So we are delighted he is going to speak to us tonight on God, Darwin and Design. Thank you. Professor Miller.

Ken Miller
Professor of Cell Biology

Denis thank you very much for that generous introduction. It is a great honour to be here and I have enjoyed a couple of days here in this beautiful city and this great university and I want to thank everyone I have interacted with and I want to thank all of you for coming tonight and especially the Faraday Institute for making my trip over here possible.

One never knows how one is going to be introduced, although I think you heard a quite fair and reasonable introduction. So I always bring my own slide so I can tell you who I really am following the distortions of introduction. I am actually a cellular biologist, I work on biological membrane structure and function. This is a photo of me and my very messy lab in Providence. I publish in journals like Cell, I used to edit the journal Cell Biology and given a background like that, research interests like that, you might wonder what is a nice cell biologist doing getting involved in issues related to evolution, which does not seem to have anything to do

with it. Well the answer is that if you allow a former student of yours to talk you into doing something absolutely ridiculous, you may get involved in it and the thing that a former student of mine named Joseph Levine talked me into was going in with him and writing a biology textbook and these are some of the editions of our various textbooks that have come out in the last two years.

There was a slight inaccuracy in Denis' introduction, these are actually used by high school students, not college students for their first courses in biology in the US. These students are usually 14 or 15 years old, so this is the grade level at which they are introduced and if you write such a book you will very quickly discover that if it has a strong treatment of evolution it becomes a point of controversy in certain of the United States and that is one of the things that has drawn me into defending my own right in these books about evolution.

Now I have to tell you, and again, one of these books or another is used probably in about 40 to 45% of the high school biology classes in the United States and I have been blessed not coincidentally with two daughters. My oldest Lauren is a wildlife biologist and she was lucky, Lauren was able to graduate from the high school in our town before our book was adopted by that high school, so she escaped, but my youngest daughter Tracy was not so lucky and I live in a small town called Rehoboth Massachusetts. It is only about 8,000 people and for quite a few years people in Rehoboth, a lot of them knew me, but not because of what I did for a living. They knew me because for almost ten years I was what you might call the commissioner of the girls softball programme in Rehoboth and softball of course is the version of baseball that is played by girls and old out of shape guys like me in the United States.

So people knew Mr Miller as the softball guy, I would run the spaghetti suppers to raise money for our youth leagues, I trained our empires, in the summer I used to coach one of our All-Star teams, but they did not really know what I did for a living until Dighton-Rehoboth Regional High School where my kids went to school purchased copies of the book with the elephant on the cover for use in the classroom. My picture is inside, suddenly my cover was blown and you might think that it is very nice to have a book that you wrote being used in the community schools in your town well maybe.

One day I was driving up to the high school to pick my daughter up after a field hockey practice, she was a very good field hockey player and a woman I knew from softball, fellow coach flagged me down, her name was Bonnie Kelly and Bonnie flagged me down and she said "Ken you wrote the book that they use in the high school now" and I smiled and I got the big dumb look on your face that you get when you think someone is about to compliment you and I puffed out my chest and I said "Yes, Bonnie I did" and she looked me straight in the eyes and she said "Funny thing is you do not seem that smart". I was never quite sure how to take that and my wife said "Do not think about it very much. Take it as a compliment".

In any event as Denis was kind enough to say a few years ago I wrote a book on evolution, defending evolution and also pointing out the way in which religious people can understand it, that book is called Finding Darwin's God. It first came out in 1999, a lot has happened since then and I wrote another book that came out this past year called Only a Theory: Evolution and the Battle for America's Soul and probably it is fair to say that much of what I am going to talk about tonight is really in this second book Only a Theory.

Now I think you all know that evolution is an issue that divides Americans and as an example of just how divisive it can be, Time Magazine, a major news magazine in the United States published a cover issue on this in the summer of 2005 and as you can see they entitled it the Evolution Wars. They pointed out that many Americans, in fact more of them in some states, reject the theory of evolution. They pointed out that our president at the time had taken a position on evolution that was not particularly helpful to the scientific community and I hope you noticed something, I did not pick this up at first, but my co-author spotted it in a flash. Look at whose textbook they superimposed President Bush's face on. Yes, that actually is our textbook and I liked that at the time, because we are always looking for new cover art for our textbook and in a year or two the state of Texas is going to buying new biology books and this just might be a winner for that state. So we will see how that goes, but to illustrate how divisive this issue can be, over a space of two years I actually testified in federal court under oath in trials on the teaching of evolution in two American states, Georgia and Pennsylvania.

In Georgia the issue was that one of the large counties had actually bought our book for all the high schools in the county, but then decided to paste warning stickers on each of the books to warn students that evolution was just a theory, not a fact, do not take it too seriously. A trial ensued, plaintiffs, parents in that school district argued that this was an attempt to promote religion which is illegal under the American constitution. I testified in that trial, we won, the stickers were eventually removed, but the more highly publicised trial came in Pennsylvania where a very small school district called Dover actually passed a rule requiring the teachers to prepare a curriculum on something called intelligent design. More on that later, but despite the size of those trials, in the elections in our country in 2006 evolution was the issue in two state wide elections for state school boards, for state boards of education and these two states were Ohio and Kansas.

Now you might wonder, because you may not have seen this in the UK, what does an election played out on the issue of evolution in the schools actually look like up close. So to help educate you in this respect I brought a clipping from the largest newspaper in the state of Ohio, Plain Dealer, about ten days before the 2006 elections. You can see the headline Evolution debate at centre of state school board race and what this article highlighted was the contest for one of the seats. The incumbent was really the leader of the antievolution forces

on the board. She is actually a professor at Akron University in Ohio named Deborah Owen Fink and she is very much antievolution. Her opponent for the same seat a pro-science, pro-evolution candidate had a very memorable name. It was Tom Sawyer you cannot miss this on the ballot.

Now what was the discourse like, what was the point of contention in this election? Here is what a radio talk show host, a very popular one, in Cleveland told his audience what is at stake in the elections, he said "If you believe in God, creation and true science for Debbie, if you believe in evolution, abortion and sin vote for our opponent" and with rhetoric like that you might wonder how did the election turn out? Well I am proud to report that in the terms of this commentator the sin vote emerged triumphantly and the reason for that is that pro-evolution candidates swept the State Board of Education elections in Ohio and as it turns out pro-evolution candidates also took control of the Kansas Board of Education and the reason in both states was because scientists, educators, public health professionals in Kansas, even the Association of Petroleum Geologists formed organisations of citizens that were pro-science and advocated for science friendly candidates in the election and they managed to win both of them and I have always felt, and I tell this to my scientific colleagues in the States, that Americans will choose science every time. If we in the scientific community climb down from the ivory tower, get out on the street and take the message of science to the public and I think that is an important thing to do.

Now you might think this is sort of an exercise in sociology, because it is interesting to see what is happening on the other side of the pond, but I want to let you know that this does not happen just in the United States, increasingly this is an issue that divides your opinions as well and there have been a number of interesting articles about this in The Economist and also articles in Nature magazine and here an article published in Nature about the antievolution movement in Europe was followed two weeks later by an antievolution letter to the editor basically saying that evolution really nothing has been proven this is an open question.

Now you might think well maybe this can happen in Europe, but surely nothing like this is going to happen in the UK, it is a big issue in Turkey, it has shown up on the continent in this way – this is a quotation from a university professor on the European continent, but surely you might say nothing like this is ever going to happen in Britain and certainly not here. Well the reality is any of you who have followed this in the UK knows is that is not exactly the case, because it turns out about two years ago the BBC highlighted a programme on the antievolution movement the United States and they thought it would be fun to poll Britons, to ask them the sort of questions that people in my country are always asked "Which do you want to see taught in schools? Evolution, creationism, intelligent design" and 40% of Britons chose either creationism or intelligent design over evolution.

Now this poll was in 2006, more recently it has been repeated and again as highlighted by the Daily Telegraph indeed it turns out the poll of the British public revealed severe doubts over the efficacy of Charles Darwin's theory of evolution to fully explain the complexity of life. Tomorrow I am going to be journeying up to Scotland and as it turns out this has also been a controversial issue in Scotland as well and some of you may have known of an almost shameful incident at a Natural Science Museum, Natural History Museum here in Britain in which the organisers were so concerned about religious objections to an exhibit on evolution that they actually covered up offending sentences about evolution with some wrapping paper so that museum patrons did not have to see them.

So what I want to assure you about is that what I am talking about is not confined to the United States, the intelligent design antievolutionism is another great American cultural export that is coming over to this side of the Atlantic as well and I think those of us in the scientific community in the UK should be prepared for. Now what happened in the state of Pennsylvania is an instructive case, the scoreboard in the small town and it's always important to emphasise that education in the United States is a local function, much more so than it is in Europe, so local boards can exercise tremendous control over. They voted to instruct their teachers to prepare a curriculum on intelligent design, the teachers at the risk of losing their jobs refused. This is to their everlasting credit, they said this stuff is not science.

Nonetheless what the board did was to vote to write its own lesson on intelligent design and they had their professional employees go into the classrooms while the teachers literally stood outside in the hallway and read the intelligent design lesson to students. Well what can you do in a circumstance like this? Well in the United States what can happen is that 11 parents of students went down to federal court and the nearest jurisdiction which is Harrisburg, Pennsylvania, the State Capitol and they filed a lawsuit. These are the citizens who did this.

The lawsuit was known as Kitzmiller versus Dover named after this unassuming woman in the blue blouse her name is Tammy Kitzmiller and it alleged that their first amendment rights as Americans not to have an agency of the state, and that is what a school board is, endorse a particular religious point of view had been violated. This lawsuit moved the trial with remarkable speed. Only about nine months after filing the case was called to order and I will tell you a little bit about the case in a second, but I think first we have to ask ourselves something and that is what does this term intelligent design actually mean? I think for the most part I would see theists people who believe in a God of any sort maybe even deists would agree that there is some sort of a transcendent intelligence behind existence and you might actually express this as the notion that there is an intelligent design to the universe and I want to tell you tonight for what it is worth that is actually a point of view that I hold myself, but that is not what is meant by intelligent design in this context.

What is meant by intelligent design in this context is the proposition that what people call design and what they really mean by that is outside an intelligent intervention is required to account for the origins of living things and what this means is intelligent design is not this general consideration of meaning and purpose in the universe, it is a doctrine of special creation. When one says the complicated structures like the bacterial flagellum or pathways like the proteins that clot our blood were intelligently designed. What they actually mean is that the genes for the structures or pathways were created in fact by a creator and that is why I call this a doctrine of special creation and that does not mean it is wrong, it simply means that is the proper way to deal with it and to call it.

Now as the trial loomed (the trial was called to order in September of 2005) for intelligent design proponents this was their great chance. They drew by the luck of the draw and that is how it is done a conservative judge that had recently been appointed to the bench by President George W Bush. The judge whose name is John E Jones III is a lifelong Republican, a judicial conservative, they thought this was the case we can win and all we have to do is to get those evil Darwinists on the stand under oath and we will break them down under cross-examination and get them to admit that evolution is just the tissue of lots.

Well you can see that cameras are not allowed in federal court, so when we have a trial in the US, any images are made by sketch artists, you can hear them scribbling away during the trial and here is your representative Darwinist on the stand, that is me in the NBC television courtroom sketch being cross-examined by attorneys for the other side and rather than something like this happening, what actually took place is the intelligent design literally fell apart during this seven week trial as anything even remotely resembling a scientific theory.

Now I was actually the lead witness for the plaintiffs for the evolution side in this trial and my job was to take what you might call the icons of intelligent design, things like the bacterial flagellum or the blood clotting pathways and basically show why the arguments used to say that the structures or pathways or genes are unevolvable, my job was to show that these arguments are incorrect. I knew that I would be followed by expert witnesses for the other side, so what I had to do basically was to explain the evidence for evolution, then I had to tell the judge what these other witnesses would say about a week later and then I had to explain to the judge in advance why what they were going to say was wrong and as it took me two days on the stand to do it including six and a half hours of cross-examination under oath, but obviously I did it and so did the other five expert witnesses for our side in this trial, but one of the things I want to review for you is the really persuasive evidence in this trial that intelligent design is in fact a religious idea and here I think the track record is exceptional and clear. The advocates of intelligent design say that students should be exposed to textbooks that describe what intelligent design is.

One of those textbooks goes by the title of *Of Pandas and People* and the content of this book turned out to be particularly persuasive and I want to show you what I mean by that. Here from this book is the definition of intelligent design and you can read it here for yourself. Intelligent design means that the various forms of life began abruptly through an intelligent agency with their distinctive features already intact, fish with fins and scales, birds with feathers, beaks and wings and so on. It sounds very scientific. I want to assure you that there is nothing in this book about genesis, Jesus, the global flood, it sounds very scientific from cover to cover.

Now before the trial began our attorneys had a great idea, they subpoenaed the publishers of this book and they asked them "Has this book ever been published earlier perhaps under a different name? Do you have the earlier editions, editorial correspondence, page proofs, that sort of stuff?" I thought this was absolutely pointless. As it turns out they got 7,000 pages of material from the publisher, the lawyers went through it. One of the attorneys called me up one day and said "Ken here is what we found". He told me what they had found and I practically fell to the floor laughing. All I could think of was did these people not learn anything from the Nixon administration? You cannot leave this stuff around, you have to burn it and what they should have burned was the fact that this book had been published earlier under a different name and the differently named book as you will see red paragraph for paragraph with this book with one very interesting and very subtle exception.

I want to show you the paragraph that matches this one, creation means the various forms of life begin abruptly through an intelligent creator; it is the same paragraph and all they had done was to take the manuscript for this book called *Biology and Origins*, fire up Microsoft Word, do a find and replace. Find the word creator, replace it with the word designer and pretend that now because it calls the creator a designer it is a nonreligious book.

Now a colleague of mine from Louisiana who also was an expert witness in the trial named Barbara Forrest went through this systematically and her job was to dig through all 7,000 pages and count up the number of times they mentioned creation or creationism that is in red and the number of times they use the term design that is in blue and you can see that in the early versions of this book it is all about creation almost nothing about design, but watch this bang, all of a sudden something happens and what happens is in the middle of 1987 suddenly creation drops to zero and design goes up like a reciprocal plot to take its place.

Clearly something astonishing happened in 1987, now I was speaking at University of North Carolina, great American state university a few months ago and I had been joking before the lecture to students in the front row, they look like a pretty bright group and they assured me that they were a very bright group. So I said "Okay, you guys are so bright" during the lecture "Tell me what happened, one of you, in 1987 to merit this change" and one young man

started to wave his hands back and forth I thought this kid must know, so I said "Okay, go ahead what happened?" and he jumped up and he turned to the whole audience and he said "I was born". What do you say to that? I said "Sir I am sure that was a remarkable event, but that is really not what I have in mind here". Here is what happened in 1987, this is a timeline of court cases in the United States, the deal with the teaching of evolution in our schools.

The very famous Scopes Trial, the Scopes Monkey Trial in 1927, it's all the way right over here, you can see it. The case involving the stickers in my textbooks Selman versus Cobb is actually right here, but there is one really important case in this timeline, this is one that went to our supreme court was Edwards versus Aguillard and it is the definitive case that identified creation science as inherently religious and therefore impermissible in the public schools in the United States.

These folks had published a book on creation science. They wanted it to be put in the public schools, but suddenly the Supreme Court in '87 says "No, you cannot". You can just imagine the panic that ensued at the [inaudible-00:23:49] the publishers, the editors and the authors, we cannot sell this book, we cannot call it creation science. So they brainstorm, anybody got an idea, got a name we can call it and somebody puts their hand up and says "How about intelligent design?" That is it, Microsoft Word find and replace, call the creator a designer and you have got an intelligent designed book.

If anybody tells you that somehow the intelligent design movement which you are seeing today in Britain is any different from good old fashioned creationism, remind them of how this intelligent design textbook came about. You take a book on creationism, you relabel it as intelligent design and you pretend that it is something new.

Now what happened in this trial in Pennsylvania has already been documented for the British public, the BBC science series Horizon did a programme about three years ago called A war on science and it talked about what happened in this town in Pennsylvania, they even went besides the usuals, the usual talking heads in this country like Richard Attenborough and Richard Dawkins, they actually went over to the other side of the pond to find a few people like the advocates of intelligent design. This fellow up here named Bill Dembski and a few people who disagreed with him like this loudmouth biologist from Providence, Rhode Island.

It was an interesting shell, but I have to say with a certain amount of American pride that I think learning from this the American science series Nova went to BBC1 better and they did a programme about a year later and I am going to show you a lead clip from that programme that will give you some idea of what was actually involved in this case and here it is.

On Nova.

I believe there is an intelligent design. In the beginning God created.

Saying that you do not believe in evolution is almost saying we do not believe that civil war ever took place in the United States.

An extraordinary court case ignites a small town.

[inaudible-00:25:45] civil war within the community there is no question.

It puts science itself on trial.

Very important things were at stake, one is a future of science education in this country.

Nova reveals the story behind the headlines.

Anywhere you turn we were getting attacked.

Witnesses started dropping like flies.

It probes the question is intelligent design a scientific alternative to evolution?

Probably the subject of a science class.

Or religion in disguise?

It is a violation of everything we mean and everything we understand as science.

Judgement day intelligent design on trial on Nova.

I can see that obviously you think that voice over was just dramatic enough. This was really an exceptional show and it won the Peabody Award which is an award in excellence in broadcast journalism. It is actually available as a DVD as a sort of a commercial for public television in the US and more importantly if you actually care to watch this programme, and I recommend it to you, because it is really quite extraordinary, you can go to the Nova website and watch it at no charge with streaming video. So the entire programme is up there and I think it is [inaudible-00:27:02] worth watching.

Well I have not told you yet how the trial ended up and what happened is just before Christmas in 2005 Judge Jones announced his decision as a result of the seven week trial and it was very clearly that intelligent design was not science, this was widely reported in the print media in the United States, it was reported of course in television and it set off celebrations around the US in many respects.

Now I would love to pretend that with this confrontation in which the intelligent design movement got to take their best shot at evolution. I would love to pretend that this settled

things, but it did not and that [inaudible-00:27:40] is why I wrote that book only in theory that was published in the middle of last year and I made three points in that book. The first thing is this battle is not over and it certainly is, I think, just beginning I am afraid in Europe.

It is not so much about evolution, it really is about the nature of scientific reason and whether it will be accepted and I emphasise this point in particular to my colleagues in the physical sciences who figure well we always thought you biologists were a little flaky anyway, so we will let you take care of this. This is actually a movement that seeks to undermine the authority of science across the board and finally I think it ultimately matters for our collective scientific future. It certainly matters in the United States where I think this movement threatens to undermine the confidence in science in a whole generation of American young people.

Now I want to emphasise what the tactics of this movement are, because you will see these tactics in the UK and to be perfectly honest weapon number one, and I do not mean to pull punches on this, is intentional distortion and I want to show you an example of what I consider to be intentional distortion and that intelligent design textbook Pandas and People. One of the arguments you will hear all the time, and you will hear at the UK too, is there is a problem with evolution and that is that Charles Darwin's theory of evolution by natural selection requires the existence of intermediate or transitional forms between species and the fossil record does not provide that, therefore evolution is not supported by the fossil record.

To make that claim this book told 14 and 15 year old students basically that evolutionists are so stupid that they actually believe that during the Devonian period lobed-finned fish like this Eusthenopteron gave rise to early amphibians like this Ichthyostega and the reason they regard that as ridiculous is because how can anyone imagine that a lobed fin like this with bones underneath could suddenly and dramatically have changed in structure like this to produce a limb that was actually capable of supporting this animal out of water and what they tell students is as follows. They ask them how many different transitional species were required to bridge this gap, we don't know, but we do know that no such transitional species have ever been recovered.

So in effect what they are saying is that what evolutioners are doing is taking a line from fish to land vertebrates and they have only got two examples on the slide. Eusthenopteron a fish that has certainly amphibian like characteristics, but still very much a fish and Ichthyostega which is an amphibian, but it is an amphibian with some very remarkable fish like characteristics, but they say there is no transitional species in between them.

Now even at the date this book was published and it was published some years ago, there is no other word for it, that statement and that claim were false, because these specimens actually exist within the context of a very well understood evolutionary series going from fish

in the Devonian to early tetrapods and it is worth noting that one of the major contributors to this knowledge, which was ignored by this book, is Jenny Clack who happens to be here at Cambridge and is in the audience tonight. So this has to be, I do not know Jenny if you ever read this book, but it would have been infuriating to look at these pages, because it bothered the heck out of me among other things, but I want to go a little bit further tonight.

Beyond just showing that the author has deliberately ignored the scientific knowledge we had about this in order to distort the case for our students and in reality this so called gap is actually part of a very well understood evolutionary transition I want to go in a little closer. Let's look at one part of this transition and in particular I want to say can we find yet another transitional form and what you might describe is the exact fish to amphibian transition between Panderichthys, a very amphibian like fish with actually quite robust fins that probably could have supported part of the body of the fish out of water much the way that a mudskipper does today and Acanthostega, an early tetrapod with distinctly fish like characteristics and I want to show you a clip of a colleague of Jenny's who actually led an expedition to try to find just such a transitional form and here it is.

In 1999 palaeontologist Neil Shubin and his colleagues set out to find just such a creature.

What evolution enables us to do is to make specific predictions about what we should find in a fossil record. The prediction in this case is clear cut, that is if we go to rocks of the right age and the rocks of the right type we should find transitions between two great forms of life between fish and amphibian.

Armed with his prediction, Shubin and his colleagues organised an expedition to one of the most desolate places on earth the Canadian arctic. About 500 miles from the North Pole where rocks of just the right age are exposed.

Money is running out, this is out, we were told this was our last shout there and then in 2004 and the third day of the season a colleague of mine was removing rock and discovered a little snout sticking out of the side of the cliff just exactly like this and he removed more rock and more rock and more rock and it became clear this was a snout of a flat headed animal and that is when we knew flat headed animal at 375 million years old, this is going to be something interesting.

They called it Tiktaalik which means large freshwater fish in the language of the language of the local Inuit people and it is one of the most vivid transitional fossils ever discovered showing how land animals evolved from primitive fish.

Over here you have a fish about 380 million years old and as a fish it has scales on its back and fins. You compare that to an amphibian you find a creature that does not have scales and

it has modified the fins to become limbs, the arms and legs and the head is very different and has a flat head with eyes on top and a neck. What we see when we look at the fossil record that rocks are just the right age is a creature like Tiktaalik just like a fish it has scales on its back and fins, you can see the fin web in here. Again when we look at the head you see something very different, you see a very amphibian like thing with a flat head with eyes on top.

It gets even better when you take the fin apart, when we look inside in the fin as in this cast here, what you will see are its bones that compare to our shoulder, elbow, even parts of the wrist, bone for bone. So you have a fish at just the right time in the history of life that has characteristics of amphibians and primitive fish. To put it another way you just could not draw it up any better if you wanted to on a drafting board to find an absolutely perfect intermediate form and interestingly it did not stop there, because it turns out at about the same time another group had found yet another fossil in the same evolutionary transition. This one is called Gogonasmus it is more on the fishy side and if you look closely at the boney structure underneath his fins you can see the bones that we can recognise as the humerus, the radius, the ulna and many of the bones of the wrist as well.

So I have a friend of mine in Colin Purrington who teaches at Swarthmore College in the United States. It's a very distinguished liberal arts college and even more so than me, Colin is a real wise guy and he likes to point that we already have pretty good understanding of this transition then what happened in 2006 this Tiktaalik was published. It plugs in right here, Gogonasmus plugs right in there and the way he put it is to tell me, because I have a reputation for arguing with these people "Ken the next time you are involved in a controversy court case and debate or something like that do not show a lot of slides, do not talk about DNA sequences that you like to do and so forth. End it all with one sentence" and here is the sentence that Colin recommended: "we have the fossils, we win," and I think that is a very good way to summarise the state of the current evidence.

Now some of you may wonder why do these folks make such a big deal, such an argument against intermediate or transitional forms. I mean who really cares where the first tetrapods came from, why is this an important philosophical point? Well the answer is it is not tetrapod origins that individuals are concerned about, it is human origins and this is actually the billboard that appeared in the state of Kansas during those elections I was talking about in 2006 and you can probably go to this site now and see Whoisyourcreator.com and you will find that these were put up by people who find the very idea of evolution profoundly threatening.

Now what is the state of evidence here? What about this transition? Well a few years ago Nature published a new fossil find, there have been many since then of this species over here Kenyanthropus platyops from East Africa, here is a previous find probably. It is of some

controversy that is often classified as homo habilis and in the issue of Nature in which this was reported this chart was produced, summarised the extensive fossil evidence for our own ancestry in just the last five million years and it is extraordinary to note that contrary what many people think if there is some kind of missing link between us and our prehuman ancestors, in fact we have so many missing links that we found that the hard part is to figure out how to connect the dots.

We do not really know which ones were direct ancestors, which ones were our cousins, which ones are the crazy uncle out in the cottage or anything along those lines. That is the difficulty not finding specimens, but I have to tell you something, because I find this significant, when I opened this issue of Nature and I read, looked at that graph, I thought I have seen that. I have seen that exact graph somewhere before, but I could not place it and then I went home that night and had dinner I thought that is ridiculous this is literally hot of the presses, how could I have seen that before and I could not figure it out.

Two or three days later, this is honest to truth, I woke up, got out of bed, walked into the shower and thought I know where I saw that before. When Charles Darwin published the origin of species in 1859 he put exactly one drawing in it. He wanted to show people what the origin of new species would look like if you had an absolutely complete fossil record and he put a sketch in the origin of species and this is part of a sketch and it is right here and the reason I thought I had seen this before is because our current understanding of human ancestry looks remarkably like the back of the envelope sketch that Charles Darwin 150 years ago put into the origin of species. The old guy got it right and he got it right the very first time.

Now that still is not as persuasive to many people as I think it ought to be scientifically and a colleague of mine named Nicholas Matski who is now a graduate student at the University of California, Berkeley suggested a way to make this clear and Nick pointed out that there is a very dull paper that appeared in an obscure journal just a couple of years ago which the investigators took every single known prehuman specimen and measured the extracranial capacity, the brain size in that specimen and then basically listed it as a function of the geological age of the specimen.

So here is all this scintillating data, it is just 16 pages of boring, boring, boring, but Nick knew there was something good in there, so what he did is something the author should have thought of, he took the data and he typed it into an Excel spreadsheet, he then graphed cranial capacity as a function of geologic age and here is what he came up with. Millions of years ago here cranial capacity and what you see and it is colour coded by fossil species, what you see is a smooth transition up to the very same range of humans today and to put it bluntly do you see a gap between humans and non-human primates and the answer is no, absolutely

not, but here we have the advantage of numerical and statistical data that make this abundantly clear.

Now I am not a palaeontologist, so I find this data interesting, but it does not warm me up the way that molecular data does. Two weeks before I was to take the stand in the Dover trial, this issue of nature with the DNA sequence of the chimpanzee genome came out. I had immediately realised this was significant. Here is the sentence from the summary article, more than a century ago Darwin and Huxley proposed that we humans share recent common ancestors with the African great apes. Modern molecular studies have spectacularly confirmed this prediction and indeed that had, but the problem with this is that in order to bring this into a courtroom I could not get on the stand and I could not talk as some of these articles did about the percent of conservation of syteny, the judge's eyes would have just glazed over.

With no disrespect intended to anyone in the audience we had to put this in terms so simple that even an attorney could understand and I want to show you how we did that and these are slides that I actually used in the trial during the courtroom. We have known for a long time that we human beings share recent common ancestors with the great apes, gorillas, oranges, chimpanzees and so forth. There is biogeography, fossil evidence, physiology, all sorts of good stuff, but here is something that is unusual and remember I am a cell biologist. We humans carry 46 pairs of chromosomes, interestingly all the other great apes carry 48. Now I know there are a lot of distinguished biologists in the room and you realise that those 46 chromosomes are actually two sets of 23. Each of us got 23 chromosomes from mum and 23 from dad. A baby chimp gets 24 from mum and 24 from dad.

So here is the question, why are we missing a pair of chromosomes? Is it possible that in the lineage leading to us a pair of chromosomes just got trashed during meiosis or during fertilisation so they are no longer there. Well the answer to that is any primate geneticist will tell you "No, it is not possible, the loss of both members of a homologous pair of chromosomes would be fatal". You would not even get past gastrulation, there are too many important genes. So there is only one possibility that is consistent with evolution and that possibility is the two chromosomes that are still separate in other primates, got accidentally stuck together in the lineage leading to us to fuse and for a single chromosome and if that happened it would drop us from 24 pairs down to 23. So that is the explanation, but here is why evolution is science and not conjecture, that evolutionary explanation leads to a testable prediction and here is the testable prediction, that is that somewhere in our genome we should carry a chromosome with evidence of having been formed by a recent fusion between two chromosomes that are still separate in other primates and if we do not get our genome and we do not find a chromosome like that then the idea of common descent with other primates for our species is very much in doubt, but if we do find that kind of chromosome that is a powerful

and specific prediction made by the theory of evolutionary common ancestry which we can confirm.

Now how would we find a chromosome like that and again if your field is not cell and molecular biology you might wonder. It is actually pretty simple, what I have drawn up here are two chromosomes, the tips of each chromosomes are covered with a very special sequence of DNA called a telomere sequence, its highly repetitive DNA is really easy to recognise and it is only found at the tips. Near the centre of every chromosome is an equally recognisable region known as the centromere, it is where the chromosome attaches to the mitotic spindle. If we carry today within us a chromosome that was formed by the fusion of two primate chromosomes, do you know what that chromosome should look like? It should have telomere DNA not only at the tips, but at the centre, at the fusion point where it does not belong and it should also have two centromeres. That should enable us to pick it out from any other chromosome in a flash. So the question is do we indeed carry such a chromosome? Well the answer is we do, it is called chromosome number two. This is also a paper from 2005, every detail that I have mentioned in human chromosome number two, even the precise fusion site which occurs in a 15 base region between base 114,455,823 and another region 15 bases over is known and it fits exactly this prediction.

Is there any way that we could explain these facts and these are facts, these are not hypothesis, theory or conjecture, is there any way to explain these facts in a way that is consistent with the view that our species was uniquely created or intelligently designed. The answer is no, there is only one way to explain them and that is evolution. That is the only other thing you could do would be to say maybe one day the designer wanted to fool us into thinking we had evolved and he rigged chromosome number two in order to trick us and the only thing I can say with respect to that is that that is what he wanted to do, he did a heck of a job, because the evidence of common ancestry was written all over our genome and not just on this chromosome.

Well, as I said, intentional distortion is weapon number one, weapon number two is a fear of evolution itself and I thought this was brilliantly crystallised by a former Senator from the state of Pennsylvania and I chose him because ironically he is the Senator who recommended Judge Jones for the bench, the guy who heard the Dover case and found in our favour and Rick Santorum wrote a book a couple of years ago called *It Takes a Family* and in that book he took a shot at evolution. He said he did not want to see evolution taught in our schools. He was asked about this by a reporter, reporter said "Why is evolution so important?" and he says "It", he means evolution "has huge consequences for society, I mean it is where we come from. Does man have a purpose? Is there a purpose for our lives or are we you know the result of chance?" If we are the result of chance, if we are simply a mistake of nature then that puts a

different moral demand on us and then he thought for a while and said "In fact it does not put a moral demand on us then if in fact we are a creation of a being that has moral demands".

Well the syntax has a little confused it there, but he was speaking without notes so I will cut him a little slack on that, but Santorum was saying that "Evolution tells us we are a mistake of nature and if that is true all morality, where all sense of right and wrong is simply an illusion". If you really believe that to be true I think that would be a profoundly threatening thing and I think it is at the basis of what many people fear about evolution.

So as a biologist I want to ask the following question, is evolution really driven by mistakes? Now an awful lot of people including biologists would say "Yes, of course it is", because evolution is driven by mutations which are mistakes that usually crop up in DNA replication or other processes associated with genetics, but that word mistake implies something that is not supposed to happen. So I want you to imagine the following, imagine an organism that never made these mistakes, an organism, like a microorganism here in which mutations never took place. If you have no mutations, you know what else you have? You have no evolution, you have no ability to adapt changes in the environment.

An organism that never made one of the so called mistakes would not survive for very long, so we then have to ask ourselves the following, maybe evolution is not really a mistake of nature, maybe organisms are actually selected for their ability to make what we call mistakes, so maybe evolution is actually an essential element of what we might call the design of nature.

Now I want to continue on this theme in a very straightforward way, Santorum asked "Does evolution not say that our lives are without meaning and purpose?" and I would say as a scientist does that mean we have to answer the intelligent design argument by claiming the adverse, namely that there is no design in nature. I do not think so, because that would imply that the form and function of living things including ourselves are the random and accidental mistakes of nature and my message to you in closing tonight is they are not, they are not the random accidental acts of nature.

So I want to explain very specifically what I mean by that, the reality is that life is material, we live in a material world, I always cite this to my students as an example of one thing that Madonna got right, this really is a material world and the capacity for life is built into the physics and chemistry of matter. Evolution therefore is an inherent and a predictable property of nature, it is not a mistake, it is more like a feature of nature and what evolutionary processes do is they explore what biologists call adaptive space and in so doing they are driven by natural selection which is distinctly not random and by natural law which is not random either.

What this means essentially is what I would call an evolutionary design to life is an inherent part of the fabric of the natural world. So here is my lesson, to especially my fellow biologist, this notion of design is not just something inspired by theology that we want to simply dismiss, I think it is scientific reality and we want to embrace it and the reason for that is I think ultimately what used to be called the argument from design is really when we look at it today an argument for evolution and I want to explain exactly what I mean by that.

Let's start with a classic, does the human body have a design? Well classically advocates of intelligent design have really echoed the sentiments of the Reverend William Paley and his book natural theology in which he argued the human body does indeed have a design and that design could only have come from the creator. Well I am going to agree part of the way with William Paley, I am going to say I think the human body does have a design, but I also want to tell you where it came from and as an authority on this I want to cite the person you saw in the video clip a few minutes ago Neil Shubin.

Neil has published last year a bestselling book in the United States, I am sure it is becoming available in the UK and it is called *Your Inner Fish*, a journey into the three and a half billion year history of the human body and what Neil argues is that the architecture, if you will the design, of the human body is the design of a fish body and that you could understand peculiarities and I am not making these up they are all in the book, peculiarities like nipples, hair, burping as modifications of a fish physiology which are now used by an organism that stands upright on land on what used to be its hind fins and as it turns out Neil also teaches human anatomy to medical students at the University of Chicago and year after year he tells me he was struck more and more by the way in which you can understand human anatomy and physiology by virtue of its evolutionary ancestry in our fishy ancestors.

This is a great book that will not only teach you a great deal of biology, but it will make you laugh out loud in 10 or 15 places and I think you will enjoy it immensely. How about proteins? This is the sort of stuff that I work with from time to time, we often talk about the design of proteins or a SH1 domain or a GTP binding site, by design in that case we mean the correlation between structure and function. Do proteins have a design? You bet they do, they have a design that is being produced in them by the process of evolution.

Does the human genome which we work on more and more in the laboratory and on computers have a design and once again I would agree that it does, but it is not the design of a draughtsman writing that genome out in paper it is the sort of design that you saw a few minutes ago that reflects our evolutionary common ancestry with other organisms. That common ancestry was anticipated of course by Charles Darwin in his second great book *The Descent of Man* and I have to tell you that one of my recurring fantasies is to meet Charles

Darwin somewhere in the hereafter and tell him about the chromosome two story and I cannot believe that he would not be smiling from ear to ear when he heard it.

Now finally I want to deal with an issue that comes up a lot when we talk about evolution and I want to start off by reunderlining the point that I have said so far and that is I think the true design of life is real, but it is the evolutionary process and it is the world of matter and energy that makes that evolutionary process possible. Here is where I see a reconciliation between both scientific and religious views of nature, I want to make this very clear how I see this. I would say that to religious people to people of faith, the source of this order and design that I have been talking about in nature and this is what science investigates is really very clear and that is to them it is ultimately God, because God is the source of everything naturally.

I would further say to non-religious people that order is still there, that evolutionary design is still real, but the order has to have another source, but here to me is the unifying principle, either way the study of that nature is exactly the same and I think this is ultimately why science is compatible with faith and that is ultimately whether a scientist is religious or non-religious, what really matters is the study of the order, the design, the architecture and the function of the natural world.

Many times when I speak in front of religious audiences they get a little nervous about that and I get questions all the time science is inherently materialistic, I have trouble believing in a discipline that is only materialistic in its outlook and indeed that is true. I think all scientists are methodological if not philosophical materialists, but I would argue that a science based on materialism does not have to be hostile to religious faith, it is not going to be confirmatory, but it does not have to be hostile and I also think that religious faith does not have to be hostile to science and to religious folks who are often sceptical about the role of materialism I like to quote a tiny little sentence from Mere Christianity by C S Lewis and here it is "God likes matter, he invented it" and I think that is the ultimate justification for scientific materialism.

If you are not a religious person and you find this a little bit too mystical, consider a very famous pronouncement about the nature of matter in the universe by a well known atheist and that is Carl Sagan and that is that we humans are ultimately a way for the cosmos to know itself. I think that has a cast of spirituality that I think even religious people can relate to even coming from someone like Carl Sagan, but many people will say "But wait a minute, does evolution not actually say that God does not exist" and on the other side of the pond, this was not very highly publicised over the US, but I got a look at this and boy did I find this funny these little stickers on the side of London buses inspired by friends and colleagues of Richard Dawkins and I like that it says "There is probably no God". A lot of people were upset by the probably, saying "Now stop worrying and enjoy your life" and I was amused by that to find out that apparently only religious people worry and of course if you wanted to export that slogan

to the US you would have to say "There is probably no God, so party on dude" and that would be a good translation of what is going on, but I want to point something out and that is that scientific opinion on this is hardly unanimous.

The new magazine called BBC Knowledge in one of its early issues this year did a really penetrating interview with Richard Dawkins, it is really quite good and then we asked two people to comment on the following proposition, is the theory of evolution compatible with divine creation? So they decided to go over to the other side of the pond and they asked an American philosopher of science Daniel Dennett at Tufts University in the Boston area about this and Dennett said "No, it is absolutely not compatible with this", but as long they were over the other side of the pond they figured they would find another American who disagreed with Dennett and guess who they picked, yes that would be me and basically I said "Yes, it is" and if you are interested in this you could go online pick up the magazine and see the two points of view, but I would also point out that about 40% of working scientists in the United States, in the AAAS, American Association for the Advancement of Science are in fact people of faith. So I think it is self evident that people can do science and they can do it quite brilliantly and still be religious and I think that is self evidence simply from statistics.

There are also this month is a very interesting BBC programme hosted by the gentleman you see up here dealing with this actual idea of whether or not one can be a Christian and in fact accept the theory of evolution and if you have seen this programme you know that the thesis of the programme is yes, you can.

What about very famous pronouncements by people like Richard Dawkins say "Here is what science tells us" and Richard must like this quote, because he actually put the same wording in two of his books. The universe we observe has 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 and I cannot tell you how many times in the US that quote has been thrown at me as saying "That is why I dislike evolution, because of the bleak worldview that it evidently requires".

Well I look at that statement and I know, because I do know Richard and I have spoken with him about this that is not even exactly what he believes even though he once wrote a marvellous book called Unweaving the Rainbow in which he mentioned this quote and said that he had written Unweaving the Rainbow in part to let people know that he is actually a rather pleasant, happy and optimistic fellow despite this particular quotation, but the interesting thing about this is from my point of view comes from the following analysis is that a scientific statement? It is certainly a statement by a scientist, but is it a scientific statement and in particular I began to wonder what would other scientists and other people who have also read about evolution said, how about, for example, John Haught who is one of my fellow expert

witnesses about the Dover trial, a theologian at Georgetown University, a catholic university in the States who has argued persuasively, I think, that Catholic theology is consistent with evolution or a great molecular biologist like Francis Collins responsible for heading the human genome project worldwide led to the sequencing of this or great geneticists like Theodosius Dobzhansky or Francisco Ayala.

I think they might look at the same data that Dawkins looks at when he says this and they might say something a little bit more like this, they might say the universe we observe has precisely the properties we might expect from the wisdom of a provident and purposeful God intent upon a fruitful and dynamic world and committed to a promise of freedom that makes genuine wealth possible and I have actually bounced this word off to those people and they pretty much agreed with me that it is something they would like to say.

Now you might say "Wait a minute that is not a scientific statement" and do you know what, I agree 100% that is not a scientific statement, but it is no less a scientific statement than what you heard from Richard Dawkins. It is a philosophical conclusion informed by science about which I think reasonable people can differ. For instance Collins articulated his point of view, this point of view in his marvellous book *The Language of God*. Karl Giberson a physicist in the States has written a book called *Saving Darwin* making as much the same point. There is a book called *Thank God for Evolution* by Michael Dowd and this is also a point of view that I articulated in my own book.

So the point I want to make here is simple and that is a claim of ultimate purpose can in fact be perfectly consistent with scientific reality, not confirmed by scientific reality, certainly not scientific, but consistent with scientific reality and as an example I would like to bring up probably the greatest evolutionary population geneticist since the 20th century Theodosius Dobzhansky in a very famous article that biology instructors around the world know in 1973 he famously wrote that nothing in biology makes sense except in the light of evolution. It is absolutely true, it is almost a credo for those of us who work in biology, but in the very same article look at what Dobzhansky wrote the organic diversity of life is understandable if the creator made the living world not by caprice. I would say not by intelligent design, but by evolution propelled by natural selection.

Then he said "It is wrong to hold creation and evolution as mutually exclusive alternatives" by Dobzhansky, himself a creationist and an evolutionist" and how can he say that. He says because evolution to him is God or nature's method of creation. Creation is not an event that happened in 4000BC it is a process that began 10 billion years ago and is still underway today. Now to go to a somewhat higher authority than Dobzhansky you might go Pope Benedict and you can see a headline from a recent statement of his creation versus evolution, class and absurdity and what the pope actually said a couple of years ago this contrast is an absurdity,

because there are many scientific tests in favour of evolution that appears as a reality we must see and enriches our understanding of life and beginning.

Well we Americans like things shorter and sweeter and if you would like something shorter and sweeter you can always go to one of our popular newspapers the New York Post and the New York Post has a nice way of putting things and they said "Evolution and God do mix - Pope" and that is a pretty straightforward statement about this and I would add that the same sentiment has been echoed in somewhat more eloquent fashion by a clergyman over here in Great Britain and in this particular case this is by Cormac Murphy-O'Connor, one of the Cardinals in the United Kingdom and you might be wondering at this point is this guy saying somehow that the Bible should be read as a scientific textbook? The answer is of course not, but I want to let you know I am not the first person to say that and I want to call your attention to an incredible book written at the beginning of the fifth century by St Augustine one of the earliest and most prolific of all the Christian writers, he is writing about the book of Genesis.

Now you can read the words up here, because they are in big type and as you read them I am going to translate them on the fly to what I think is 21st century English. Even a non-believer according to Augustine can study geology, astronomy, zoology, botany and other scientific fields and can gain scientific knowledge from observation and experiment.

Now the worst thing that could happen would be for a nonbeliever to hear a Christian explaining the bible, talking nonsense on these scientific topics. We Christians have to do everything we can to prevent the embarrassment of non-believers showing up scientific ignorance in a Christian and laugh against the scorn. Augustine was warning people, he was not concerned about Darwin or evolution, he was warning people at the beginning of the fifth century, do not read Genesis as a scientific text, because if you do and you are mistaken the non-believer will disregard the real message of scripture which to him of course is the message of salvation.

Now once when I showed this quote to a group of geneticists, a person raised his hand and said "What kind of science would we get if we follow the ideas of a weird fifth century mystic like Augustine and here is a likeness of Augustine. I think it is a fair question, so I said "Let me answer it with an example of a particular individual who is so influenced by Augustine's thought that he joined a religious order founded according to the precepts of St Augustine". He was quite successful in that religious order, his colleagues thought very highly of him and eventually they made him the Abbot of the Augustinian Monastery of St Thomas in Brun in what is today the Czech Republic.

Now at one point in his life this devout clergyman got interested in what today we call a scientific question and he decided to read scripture, he read it every day, to pray, he prayed every day, but to answer the scientific question what he did was to go into his garden and do experiments. That Augustinian priest was Gregor Mendel, the founder of the modern science of genetics. What kind of science do you get if you follow Augustinian precepts answer you get darn good science you get genetics and I think that is a profound statement about the ultimate capability again of science and religion.

So who summarises it best sometimes I am asked by people "How do you see evolution?" and I have to tell you I would like to use my own words, I take some pride in being able to write with a small amount of skill, but I have to say when someone asked me that question I always say "I am sorry, I am going to steal the words of somebody else" and I am going to steal it off somebody who wrote these words a century and a half ago. This person when summarising his own views of evolution, did not say that he thought evolution was depressing or demeaning or demoralising in some way.

This is the same person who kept this page in his notebook, a page that many of you probably have seen. I saw it myself with my own eyes for the very first time a year and a half ago at the American Museum of Natural History in New York and it just sent chills down my spine to see the words I think and to see this sketch in this guys own hands. The very first sketch of this kind ever written down anywhere and at the end of a famous book that you have all heard about he said I think there is grandeur in this view of life with its several powers having been originally breathed into a few forms or into one and that while this planet has gone cycling on according to the fixed law of gravity. From so simple a beginning endless forms most wonderful and most beautiful have been and are being evolved, those are the concluding words, the last sentence of the origin of species by Charles Darwin and I think those are warrants to live by.

Thank you all very much.

Question and Answer Session

Q1: More recently proponents of ID have been couching their theory in terms of intellectual freedom and trying again to get it in, I was just wondering if you could tell us just how successful they have been?.

Miller: Yes, that is a good question and the point that you make is proponents of ID have actually dropped the use of the word of ID and instead they have introduced in several American states, into our state legislature, bills they call academic freedom bills and they allegedly give teachers and students the freedom to question evolution and ensure that they will not be sued, they will

not be fired, they will be disciplined and so forth. Well I am in favour of academic freedom, I think academic freedom is a great thing and I think teachers should be able to discuss anything they want, freedom with their students and I think students should be able to question not just evolution, but everything from the capitalist system and democracy all the way down to the labour theory of capital.

I think all these are good things for people to question, but here is the issue really and that is whether or not under the guise of academic freedom patently false information will be protected when it is brought into the science classroom basically for propaganda purposes and I am deeply concerned about that. A bill of this sort has failed in Florida, a bill of this was voted down in New Mexico, a bill of this sort was rejected by the legislature in Kansas, but a bill of this sort was signed into law by the governor of the state of Louisiana and is now the law in that state.

Now those of us concerned about this are waiting to see what happens in terms of what materials are brought into the classroom under the guise of academic freedom and we are deeply concerned about this. I am also not proud to say that the governor of Louisiana whose name is Bobby Jindal is a graduate of my own university, Brown University and in fact was a biology concentrator at the university, though I am also quick to say I did not teach him, he was not in any of my courses. I should also point out for those of you and I saw a few smug smiles when I said that the governor graduated from my university the leader of the Discovery Institute which is the organisation based in Washington state that advocates for intelligent design is Steven C Meier who holds a PhD in the history and philosophy of science from Cambridge University. So no-one's educational hands are clean, but this is indeed the new strategy, people have seen through it in several states, but in at least one state, so far it has been successful and I am concerned about it.

Q2: Would you accept that there is a great deal of cruelty and suffering built in to the need to survive through a evolution.

Miller: Of course I would accept that. How can anyone say anything else?

Q2: How do you live with a God who set that in motion?

Miller: Well I think the answer to that and this is actually an objection to the theory of evolution that one often hears from creationists, which is to say that the evolutionary cruelty of the struggle for existence, the survival of the fittest, is

simply not compatible with the God and therefore they are going to reject the whole idea of evolution. All that evolution says, and I am always quick to point this out to religious people who make this objection, I do not think that is where you are coming from, but I point this out to religious people as all the natural selection says is that everything that has ever been born will eventually die and I read a book once that had a phrase in it that said remember man thou art dust into dust thou shalt return says the same thing. Darwin did not write that book, somebody else wrote that book, so the reality of death is out there.

To those people coming from the other side of the argument who say how can you believe in God when nature is so cruel, I often ask them something very simple "Explain to me how you design a material world in which there is no death and there is no suffering", because it turns out if you design an existence in which we are creatures of matter and yet there is no death, you also make that world static, fixed and unchangeable, because in effect you are saying the creatures will be immortalised and with the immortality comes the absence of any possibility for change, of any possibility for perfection, of any possibility for evolution per se and I would argue that the panorama of evolution with all the cruelty and suffering that we all know about in other organisms and even in our own lives, I would argue that that really is where the beauty and the extravagance and the creativity of life comes from.

So I am sceptical of the notion that people who say "Existence is too cruel to allow of for the existence of the creator" have really thought carefully as to how you would design a material existence in which that was not a possibility and still preserve the beauty and as I say the extravagant creativity of life to see the world. So that is the way I see it.

Q3: With reference to your last statement is the landscape of Mars not a world without death, so there is no life, but it is still dynamic and changing due to the weather patterns and other events that occur there.

Miller: Can I ask you a personal question sir? Are you a geologist? [No] Oh okay. To me the landscape of Mars is only exciting if one is a geologist. Please do not take that the wrong way, some of my best friends are geologists as they often say, but I put to you the following question and that is that sooner or later the European space programme, the Americans, the Russians, somebody is going to get to Mars, do some really good exploration. I really hope it happens in my lifetime.

I think the single most exciting thing that we could discover on Mars or any other planet would be some form of life. I mean I think that would be astonishing and therefore, this is my own personal prejudice as a biologist as opposed to a geologist, I regard life as the single most interesting thing in the universe and therefore to me Mars is not nearly as interesting without life as it could be with life.