# The Science Studio
# With Peter Atkins

**ROGER BINGHAM:** My guest today in The Science Studio is Peter Atkins, who is professor of chemistry at the University of Oxford, fellow of Lincoln College there. He's the author of nearly 60 books, including *Galileo's Finger*, which is the 10 great ideas of science, a world-renowned textbook, *Physical Chemistry*, which is now in its eighth edition, and this new book, *Four Laws That Drive the Universe*.

He's been a visiting professor in France, Israel, New Zealand, China, Japan, travels widely, and we're glad to have him here in La Jolla. Peter, welcome.

**PETER ATKINS:** Thank you very much.

**ROGER BINGHAM:** I was going to say that *Galileo's Finger*, in my view, is a book that actually should be given to everybody to read because it sets out here ten of the absolutely fundamental ideas in science. I think there's a case to be made that there's a dearth of information about science in the general public. I mean, is that why you wrote this thing, or?

**ATKINS:** Yeah. I have this vision of science as being such a wonderful way of looking at the world, and I don't like to think of people going to their graves without having experienced the joy that can come from really deep understanding.

So I sat down to share with people what I thought were the really central, pivotal ideas of modern science, and the result is *The Finger*, as you see. Actually, privately, it was kind of an anti-Alzheimer's book because I wanted to exercise my brain before it got addled. So I had to learn a lot in order to write it, but I wanted to share the vision that I had with people.

**ROGER BINGHAM:** You quote here, there's one chapter here, which is basically about the second law of thermodynamics. I remember reading some years ago your classic text on the second law of thermodynamics, and let me link that to the famous quote by C.P. Snow, who said that not knowing the second law of thermodynamics is like never having read a word of Shakespeare. And he was making this connection between them.

**ATKINS:** Yes.

**ROGER BINGHAM:** There were two cultures and we should try and get rid of that. That more people should be scientifically literate and the scientists themselves should be humanistically literate, I suppose.

**ATKINS:** Yes.

**ROGER BINGHAM:** Take me into that a little bit.

**ATKINS:** Well, I think when I begin my lectures to my undergraduates at Oxford on the on the second law, I begin by saying that in my view, no other law has contributed more to the liberation of the human spirit. And of course, they giggle because they think that's hyperbole and so on. But I actually think it is true, and I think the second law of thermodynamics, which is this example of difficulty and complexity and erudition in order to understand it, is none of those things.

What it is a way of looking at the world that enables you to understand why anything happens at all, and I think at the very minimum people ought to know in the world why anything happens because they're surrounded by things that are happening.

And it's extraordinarily simple, too. All it says, basically, in a simple way, is that things get worse. And everyone knows that anyway. But to be slightly more precise, it implies that matter and energy spreads in disorder, and so it gets worse in the sense of the quality of energy is declining because it is less useful when it is dispersed than when it is collected in a small region.

But the extraordinary thing is, and really the beauty of the second law is that you can tap into that dispersal of energy with gear wheels, pistons, or biochemical processes, metabolic processes and so on and use the dispersal of energy, this sort of corruption of energy, to drive other things into existence.

So we eat and the metabolic processes inside us really disperse the products of digesting the food and the dispersal of the energy. And they link that to other processes that go on inside us, like the joining together of amino acid molecules into a protein.

So as we eat, so we grow. And so you can understand, you know, our growth. But we can also understand why an internal combustion engine works as well; why a steam engine works. Why anything works. And we can also really begin to understand what drives the mental processes in our brains as well because that could be seen to be a way in which the dispersal of energy through metabolism and so on, linked by metabolic processes, organizes the more or less random electrical and chemical currents in our brain and turns these random currents into coherent currents.

And that is manifest as works of art, acts of valor, acts of stupidity, acts of understanding - whatever. And so you really do find the springs of creativity by looking at this extraordinarily simple law.

**ROGER BINGHAM:** You had a question in the chat on entropy, which is why do men have nipples.

**ATKINS:** Yes.

**ROGER BINGHAM:** And you made a link between the two. Would you just run through that, because I thought that was a very interesting analogy.

**ATKINS:** It doesn't sit quite as well in the book as I first wanted to, because I wrote the book backwards. Because I'm a -

**ROGER BINGHAM:** [Interposing] Hebrew.

**ATKINS:** - yeah, I'm a bottom-uppist rather than a top-downist, and so I wanted to put gravitation and all that sort of stuff in first and then energy, then entropy, and so on, and then end up with evolution, because evolution is just the manifestation of the working out of the second law using the fangs of cheetahs, basically.

But on reflection I decided that having a chapter on general relativity first might dissuade people from reading the second chapter, so I turned the book inside out and so evolution now precedes the second law. So that particular remark that you've reminded me of doesn't sit quite as strikingly in the book as it was when I first wrote it.

But the second law, saying that things get worse, really does manifest itself as the emergence of the biosphere through evolutionary processes and so on. That everything from the first replicating molecule to ourselves and whatever will follow us has been driven by the processes that are summarized by the second law, and the fact that men have really emerged from their ancestors still with their nipples intact is really a sign of the second law at work.

**ROGER BINGHAM:** So in the book that you have here called *Four Laws That Drive the Universe*, how do you expand to that?

**ATKINS:** Well, there are three more, basically. The trouble is there are four laws of thermodynamics and the most complicated thing about thermodynamics in my view is the numbering of the laws, because the first law to be formulated is the second law. The first law was the second law. The zeroth law was an afterthought but is more basic than the first and the second, so it had to be called zero rather than one.

And then you've got the third law, which was discovered fourth. But in a sense, once you've got past the numbering of the laws there are just four of them. The zeroth law is really a statement that enables you to specify what you mean by temperature. The first law is effectively the conservation of energy, so it enables you to talk about the extraordinary

fact that whatever amount of energy we were given in day dot, we've still got - we can't do anything about it. So there's never going to be an energy crisis because we're stuck with the total amount of energy.

The second law, the third of these laws, is about entropy and so on, and whereas the first law is about the quantity of energy, the second law is about the quality of energy, which is ineluctably declining. The quality is declining. So we're actually moving towards an entropy crisis, not an energy crisis.

And the third law is a slightly more sophisticated law, which enables you, really, to apply the concepts of thermodynamics in a very fruitful way to chemistry.

**ROGER BINGHAM:** All right, so given the difficulties of explaining this, I assume, for general audience, what happens when you get the devil's advocate or the devil's Luddite problem, I suppose, which is, look, as long as the car starts when I turn the key, that's all I want to know.

**ATKINS:** Yeah, but I can listen to a piece of music and take pleasure from the simple wallowing in the sound. I can take pleasure from a sculpture, painting, and so on simply by looking at it and thinking that it's pretty.

But the depth of enjoyment comes from understanding what lies underneath these things. To understand the structure of music really is so rewarding. You don't always need to turn on your understanding node, your comprehension of the structure of a piece of music in order to enjoy it, but if you choose to then it depends your enjoyment.

And I think that science is all about - well, not all about, but one major activity that science achieves is the deepening of enjoyment of being alive. And to understand why things work, why anything happens at all, which science provides, deepens one's enjoyment of being alive.

You know, science is useful, of course, and is the only reliable way we have of discovering anything about the workings of nature and fabric of the world, but on the other hand it is also an instrument of pleasure because it just enables you to look at anything and say, "I understand why that is so."

**ROGER BINGHAM:** Can you put a finger on when you thought you knew you had to be an explainer?

**ATKINS:** It probably came as I discovered that I was not much of a discoverer. So it's much easier to explain than it is to discover, and I have the greatest admiration.

**ROGER BINGHAM:** Do you think that?

**ATKINS:** What, that I have the greatest admiration?

**ROGER BINGHAM:** No, I was wondering if you really thought it actually is harder to discover than to explain.

**ATKINS:** Of course. Yeah, I was going to say, really, that I have the greatest admiration of those who can go out into the world and turn over an intellectual stone and discovering something that has never been seen before. I think that's quite an extraordinary talent and the thrill that comes from new discovery; it's Columbus-like, really. I've given that up because I did some of it in my youth and my middle ages and so on.

**ROGER BINGHAM:** And you got a prize, there were some prizes for that.

**ATKINS:** Yeah, but nothing serious. But I then found that I had some sort of talent for exposition, and then once you've written one book that is successful your publishers are like flypaper, really. They trap you and you can't flutter your wings and get away, so you get drawn into more and more exposition, which is much easier.

And what you're doing is expositing on what geniuses have discovered, second-hand, second-rate, basically.

**ROGER BINGHAM:** What would you have liked -

**ATKINS:** [Interposing] It's excruciatingly important, extraordinarily important to do, because the young need to be brought to the joys of science so that they can take pleasure from the world in the way that I described before.

So I like to really - I'm afraid it's not an analogy that would go down well in Southern California at the moment, but I like to think that through my textbooks I ignite a fire - a fire of enthusiasm and understanding. And through books for the general public, I spread the fire. So my apologies for drawing on that analogy, but -

**ROGER BINGHAM:** [Interposing] Since we've just had a fire here.

**ATKINS:** Since you've just had a fire. But I think that is really what I want to do.

**ROGER BINGHAM:** If you had been a discoverer what would you have liked to have discovered?

**ATKINS:** Oh, there are only two serious problems left for science, and one is the origin of everything and the other is the nature of consciousness. So I'd like to have wrapped those two up. But maybe I'm pretty good at doing titrations and so on, but I knew I'd never answer those two, so cut my losses and get into the expositing game.

**ROGER BINGHAM:** I'm actually surprised to hear you mention consciousness because I never thought that that would be something that you'd be -

**ATKINS:** [Interposing] Well, why not? Those two problems are so different in type and will have answers that are quite different in type as well, but they are deeply challenging questions. There's no hope that I can make a contribution to either of them, but I think that it's fascinating to see the edging towards understanding these two major problems.

Given that you have a life and you've got to spend it in a laboratory, I wouldn't want to spend it doing titrations. But I would be prepared to sacrifice a life to understanding the answers to those two questions.

**ROGER BINGHAM:** The starting of all of this - let me give you an example. I remember that the reason I actually read *Chemistry* was that we had a chemistry teacher who was a very dynamic person. His name was Mr. Green. He would take a test tube, he would put something brown in it, pour on something colorless; it would turn purple, give off fumes. And we all thought this was rather Merlin-like and actually then went to the chemistry and discovered it was all about spins and orbitals and things like that. And that was not taught so well, and that was a little bit depressing. But the initial thing was this marvelous enthusiasm of a teacher. Did you have the same experience?

**ATKINS:** That of course came into it. If I were a government and I had money to pour onto people, I would pour it onto the teachers of the young because I think it is of crucial importance that you get people hooked on the joy of science, once again using that phrase, as early as possible.

But I think my intellectual history was certainly driven by a teacher who inspired me. Not Mr. Green but in this case Mr. Wood. But also, I think this is probably real, that I did find mathematics just a bit too difficult at the time, although I have improved since then. But as a young adolescent, I found mathematics a bit beyond me. So I wasn't very good at physics, and for a young adolescent, biology was far too embarrassing because there are all these things reproducing all the time, which seemed to me to be rather naughty, really.

And so I was left with something in the middle, which is kind of strange. I'm really glad that I did chemistry, because people have called it the central science. You can stand in it with one arm reaching out downwards into physics or understanding of its principles, and you could stretch your other arm out upwards into biology and see the extraordinary properties of the biosphere.

So it does put you right in the heart of science, and on a platform where

you can reach in both directions. And I think in a way, *Galileo's Finger* is a manifestation of that ability to take a global view of sciences.

**ROGER BINGHAM:** So you were born in absolutely the height of the Battle of Britain, right?

**ATKINS:** Yeah, 1940.

**ROGER BINGHAM:** In the south of England. So there's dogfights going overhead - not that you were paying much attention. Then you went to school locally?

**ATKINS:** Yeah, ordinary sort of school, a village school. Then to what in England we would call a grammar school, which was kind of a selective school where I dropped out at 15.

**ROGER BINGHAM:** Because?

**ATKINS:** I couldn't stand it. In particular, I couldn't stand the sport.

**ROGER BINGHAM:** How can you drop out at 15?

**ATKINS:** Well, because -

**ROGER BINGHAM:** [Interposing] Is it legal?

**ATKINS:** The school-leaving age was 16. My birthday is in August. So the end of the school year is in July, so I didn't have to go back at 16 as it were, so I dropped out at 15.

**ROGER BINGHAM:** And did what?

**ATKINS:** I then became a lab assistant for Monsanto Chemicals, actually, and they were percipient and a benign employer, and I have a great respect for what they did, because they saw that maybe I should be levered out of the gutter. I went to evening school in a local college and after about two years my employers really suggested that I was wasting my time working for them. That's a polite way of saying get lost.

And so I wrote to - I suppose in those days there was no central clearing house for universities as there is in the UK at the moment, and I wrote 50 letters to the 50 universities saying is anyone interested in me? Southampton interviewed me and offered me a position, but then because I hadn't done the A-level examples and the matriculation examinations, entrance exams - at least I hadn't done the courses - I took them and got rather dreadful grades.

So Southampton said we're not interested in you, and I think that was one of the saddest days in my life, really. So I started again and I wrote round to another university saying that are you still interested in me?

And to their everlasting credit and it's really why I have the greatest affection for them, the University of Leicester - Leicester, in the middle of England, as you know - offered me a place a week before the academic year began. So I resigned from my lab assistant job and went to Leicester, where I did a chemistry degree.

**ROGER BINGHAM:** Did they ask you to go for an interview at Leicester?

**ATKINS:** Yeah. I say they offered me a place a week before; I went up, as it were, nine days before for an interview, and then on the eighth day I got this offer.

**ROGER BINGHAM:** That's actually remarkable, isn't it, with such a rocky beginning.

**ATKINS:** Yeah, quite. The advantage is I think that it really shows that people can do this if they're determined to and if they've got the support. I knew what the driving force for this ambition was; it was the *New Scientist* magazine. Because in those days, *New Scientist* magazine, I can't remember quite when it came out, but it must have come out in - can you remember?

**ROGER BINGHAM:** Yes, because the first -

**ATKINS:** [Interposing] Mid-'50s?

**ROGER BINGHAM:** Yeah, Beyond Belief One was in their 50th anniversary issue, which was in 2006. So it was '56.

**ATKINS:** '56, you see? And I took *New Scientist* and one of the series of articles that they had in it in those days were biographies of scientists. And it struck me that the common denominator of all these successful scientists was that they'd been to university. And so it seemed to me that if I was going to be a scientist, then that was something I really had to emulate.

**ROGER BINGHAM:** So I also grew up with *New Scientist* as well, so that's hugely important to have that kind of thing available. So you go to university, you're at Leicester. You get a bachelor's degree, BSc in chemistry, and then at that point you're thinking, what am I going to do now?

**ATKINS:** Well, you remember that I was turned down by Southampton; by whatever providence there is that decided that he would move a professor from Southampton to Leicester. This is the person I also wanted to work with, but he came to me. So I did my Ph.D. at Leicester with this person who'd moved from Southampton, which is a nice irony, I always think. So I did Ph.D. there.

And then I was offered an extraordinary fellowship, which I'd like to say

a few words about, because I have strong feelings about it. In those days, there were the so-called Harkness Fellowships of the Commonwealth Fund, based in New York. Harkness is - excuse me, [unintelligible] which sniffed around England and one or two other countries, Australia and so on, for people who they thought may become opinion-formers in the future, and then brought them to this country and told them to go out and fall in love with it. And I got one of these. It's not just for chemists; they're for belly-dancers, politicians, whatever.

And so I got one of these as a condition of the fellowship that not only should you do research for however long you're here or whatever little study you're going to do, but they gave you a car and told you just to drive around the country, basically, and get to know it.

And so I did. I came to UCLA, which was another formative experience. I found and worked with someone there for whom, although he's dead quite recently, Dan Kivelson, for whom I have the greatest admiration. And he was also intellectually formative for me in a particular way. And then towards the end of I suppose May - I was there for nearly a year; came in September - in May got into this car and just drove everywhere and got to know this extraordinary country. Then went back to Oxford, where I'd been offered a position.

But that particular program I think was a jewel in the crown for bringing all sorts of potential friends of this country to this country, letting them see how it worked, letting them meet the people, letting them see its beauty; getting them to see something less than its beauty in some places.

And then the Harkness Foundation about 10, 12 years ago terminated the program, cut it down and applied their money to what they thought was more appropriate. But in my view and in many previous former Harkness fellows, it was a scandalous redirection, misdirection of funds, of short-termism in the extreme. Because look at all of us. There were about 20, 30 a year of us, and we're now back in commanding positions in the UK. We're in government, we're journalists, we're artists, we're certainly opinion-formers, and we're judiciously friendly, let me put it that way. We're not just head over heels in love; we're just judiciously friendly with this country. And for that flow of friends, friends that you need now more than you ever needed, terminated, I think it was a dreadful decision, really.

**ROGER BINGHAM:** The money was directed to what instead?

**ATKINS:** Well, to bringing people, social workers and things like that; worthy people, but not people who control the wheels.

**ROGER BINGHAM:** Parents. Did they have any interest - I'm just flipping back a little bit because we sort of got very quickly -

**ATKINS:** [Interposing] No, none whatsoever.

**ROGER BINGHAM:** No interest in science?

**ATKINS:** None whatsoever. No. In fact, I was a deep disappointment to my father in the grounds that he thought he'd have a son who could go to football or soccer matches with him, but since I hate sport that didn't come off. And a deep disappointment to my mother, who wanted me to be useful - you know, to be able to be a plumber or something like that. And since I wasn't the plumber, I was not terribly useful. So perfectly nice people, but not -

**ROGER BINGHAM:** [Interposing] Formative influences.

**ATKINS:** Not formative, yeah.

**ROGER BINGHAM:** Did you toddle off to the local church and do Sunday school?

**ATKINS:** Oh, yeah. Parents in those days found it an ideal way of getting offspring out of the house one day a week, and so certainly I went to a Church of England sort of church.

**ROGER BINGHAM:** When did you start thinking about religion or not?

**ATKINS:** When I got to university. I have to be quite clear about that; it was the liberation of thought that I encountered when I moved away from home and came into an academic environment of a university.

**ROGER BINGHAM:** The interesting thing is - and Dan Dennett made this observation in a talk fairly recently - that if you actually do nevertheless apply the information, even religious information, the studies and so on, that people can then make their choices later on. And he was remarking that the English system, which has that in place, T.H. Huxley, Thomas Henry Huxley, Darwin's bulldog, was very instrumental in putting that into place, of course a scientist, a man who defined himself as an agnostic, I think he was the first use of it, of course.

**ATKINS:** Quite so, yes.

**ROGER BINGHAM:** So you get to university and the scales fall off.

**ATKINS:** Exactly. That's exactly what it was, really.

**ROGER BINGHAM:** Other people at university at the time that you - who did you meet? Do you have any memories of people you met -

**ATKINS:** [Interposing] Oh, yes.

**ROGER BINGHAM:** Formative influences also?

**ATKINS:** Well, the only real formative influence was my Ph.D.

supervisor who, funny man, really, but had an extraordinary insight into the nature of matter. He was no use as a mathematician and he was an awkward customer to other scientists. I got on with him warmly. I think since in my books I do try to stimulate insight and convey insight and I can certainly trace that sort of attitude to him, and I respect him for that.

Dan Kivelson, the next person along in the list when I mentioned him when I worked with him at UCLA, also had insight. But he really also had some mathematical ability. He was able to express concepts, he was able to mathematize concepts and that became a very important component of my toolkit as well.

**ROGER BINGHAM:** So what kind of science were you doing? Let me context it in the sense that the general image that people tend to have is this sort of Crick and Watson double-helix thing. You're going to the pub, you have a couple of drinks, you fiddle with some tinkertoy models, you have a double helix, and you get a Nobel Prize.

So what were you actually doing? Was this bench work?

**ATKINS:** My Ph.D. was on bench work. It was using electron spin resonance to study the free radicals that are produced in a variety of materials by radiation damage, really, and trying to infer the structures and electron distributions in these radicals. And although it was bench work, I drifted towards theoretical analysis, and when I joined Dan Kivelson it was also related to magnetic resonance, but it was entirely theoretical then.

**ROGER BINGHAM:** Is there anything that you at all remember that the general public could connect with in any sense?

**ATKINS:** Well, radiation damage is clearly something that people can connect with, and we were looking at radicals produced in phosphates like bone and so on. So potentially, there was some medical interest in that, although we never went down that particular path. The stuff I did with Dan was much more recondite.

**ROGER BINGHAM:** When did you start lecturing and when did you start writing?

**ATKINS:** Lecturing, when I got back to Oxford, so 1965 when I started to lecture like everyone. And writing, the first book was, in fact, an elaboration of my Ph.D. thesis, which I did with my supervisor. And that was published in about 1969. I was writing it while I was traveling around this country.

**ROGER BINGHAM:** When did you decide you wanted to communicate for a more general audience?

**ATKINS:** That emerged. The first textbook was 1970, and it was at that point that I was on the sticky paper of my publishers. I enjoyed writing it and felt that it enlarges one's reach. So it enables you to spread your approach and attitudes to topic out of your classroom and touch minds throughout the world.

**ROGER BINGHAM:** In your view in having written these books and so on, taught widely across different realms of science, who do you think were the great scientific geniuses? Who's in your top five?

**ATKINS:** Oh, my top five.

**ROGER BINGHAM:** Or three.

**ATKINS:** Yeah, or three, or whatever. Well it must be someone like Newton, who was able to bring mathematics into science and give humanity extraordinary power of prediction. Not just prediction, but setting up theories with spine that they could stand up to experimental investigation. And his intellectual descendent, Einstein of course, who did the most remarkable things with mathematics in terms of their application to the world. Darwin must come into that pantheon because he saw this essentially simple idea that accounted for the biosphere. The great ideas of science and the great scientists are those who have acorns of ideas, which flourish into forests of oak trees of explanation, and Darwin certainly did that. Galileo comes into it because of his emphasis on the scientific method. So I would certainly put those. I could certainly do rank two. Those would go into rank one of my paradise.

**ROGER BINGHAM:** Four men.

**ATKINS:** Yes. I mean women didn't have much of a chance in the old days. There's no excuse now for them not moving onto the pantheon of the brilliant. Well, family things are still an obligation, of course, but the excuse is less now and there is respect for what they can do. And let's hope that the next fantastic discovery is made by a woman.

**ROGER BINGHAM:** I want to go back to those four but before I forget this, why is the book called *Galileo's Finger*?

**ATKINS:** It's quite an interesting title, I thought. But yeah, that's one of the reasons. But the real reason is - well, it's sort of a real reason - the irony is, of course, that Galileo's finger was cut off while his body was being moved to where it currently lies in Santa Croce in Florence, Italy, and it's in a pot in the Museum of the History of Science in Florence. And the irony is, of course, it's probably the only true relic in the whole of Italy. Which is, I think, very neat in irony.

But the reason I use it is to point to a new direction of science. Well, I use it in two ways; one is a new direction. When the experimental

method took us away from thinking about what the world should be like, which is a kind of summary of ancient Greek science, to discovering what it is actually like by going out and doing things and poking it, seeing how it responds.

And the second reason for calling it *Galileo's Finger* is that I also like to think of it as admonishing us a little bit. Being cautious about where science is going; the worries of cosmology and string theory perhaps never being testable in a certain way and going back effectively to Greek science. So it's both a new direction but an admonishing icon, if you like.

**ROGER BINGHAM:** All right, so let's just put these four together again. We've got Galileo, who has a certain problem with the church in his era and finally gets an apology 300 and whatever it was years later. We have Newton, who's actually reading deeply in and is sort of in a mystical realm of the bible, searching for biblical translations and so on. Einstein, who had quite a lot of things to say about religion, and the believing in Spinoza's god of the universe. Who was your fourth one? Darwin, who was originally going into the church. So throughout the history of science and up to the present day, of course, there's this conflict going on and you have written quite extensively on these issues.

I have a review that you did of *Darwin's Black Box*, which is by Michael Behe, who is a proponent of intelligent design. And this is obviously a very harsh review. You obviously don't think that there's much to these things. It says here "With hard work and even the possibility of progress dismissed, Dr. Behe waves his magic wand, discards the scientific method, and launches into his philosopher's stone of universal explanation - it was all designed. Presenting this silly, lazy, ignorant, and intellectually abominable view, essentially discarding reason and invoking that first resort of the intellectually challenged - that is, God - he presents what he thinks is the most wondrous of theories: that the only way of achieving complexity is by design."

You obviously have some fairly strong opinions about this.

**ATKINS:** It sounds like it, doesn't it? Yes, yes.

**ROGER BINGHAM:** It does, doesn't it? And a lot of people, in fact, would agree with you on this. What's your position on all these things?

**ATKINS:** Well, that intelligent design is an abomination. It's a representation of intellectual laziness driven by the desire to turn this country and as many other countries as possible into a theocracy.

It's quite deplorable, and it is so alien to the scientific spirit of giving a non-explanation. And also, of course, which is another strand of the intelligent designers' approach to these things, misrepresenting results. It

is a scientific abomination, and really, I think people who value the power of the human intellect should ensure that our children are not contaminated by this extraordinarily seductive, lazy abomination.

**ROGER BINGHAM:** The laziness thing turns up in other things that you written, again, and I think this seems to be a theme that you're just really, if I may say so, irritated by people just not applying the appropriate tools for examination of this problem.

**ATKINS:** Exactly. I mean people give in at the first fence in intelligent design. They say, "This can't ever have evolved under the pressures of natural selection." What they really mean is that we're too stupid or too lazy to think of how it might have come about. There's nothing in the biosphere that, in principle, cannot be understood in terms of evolution.

But science is hard work, and scientists really have to struggle. Scientists aren't sliding downhill on toboggans; they're actually climbing mountain peaks. And while all these intelligent designers are tobogganing down because it's a nice, easy way of getting places, we scientists are really struggling to reach true understanding, and it's terribly hard work, and at the same time terribly rewarding by the time you get to the summit.

**ROGER BINGHAM:** So here's another passage from the, The Templeton Organization currently has a website where there's a number of people who give their opinions to responses to the question "Does the universe have a purpose?" And at the end of yours, which you start, your answer is, No. You should say, "We should not regard as great the questions that have been invented solely for the sake of eliciting puzzlement. I regard the existence of this extraordinary universe as having a wonderful, awesome grandeur. It hangs there in all its glory, wholly and completely useless. To project onto it our human-inspired notion of purpose would, to my mind, sully and diminish it."

**ATKINS:** Yeah. I wrote that. I'd forgotten I'd written it, I'm glad I did. It sounds rather good, the way you read it, as well, and I believe every word of it. I think a lot of theology is grappling with phantoms. So theologians have invented this almost self-consistent subject, which has no contact with physical reality at all.

And they invent all sorts of questions, which they then taunt humanity with. One of them is cosmic purpose. And they say there must be a purpose; you and your science can't explain it, and typical of theologians they don't respect the power of the human intellect anyway, and they infer that no one will ever understand it. It is ineffable; God's purpose cannot be discerned.

And of course those are fine words, but utterly meaningless. I mean, why should the thing have a purpose? They've invented this question in order

to taunt us, and most of the questions that theology grapples with like theodicy, the problem of evil, are purely invented for the amusement of theologians. If they would admit that what they're doing is playing some huge game of Trivial Pursuit, then it'd be great. We could watch them; they could have a good belly laugh about some of the answers they've come up with.

But they're not real questions. I could, for example, propose that there's a belt of planets between Mars and the Earth which has no effect upon the orbits of the known planets and there'll be a great deal of scholarly discussion based on why these planets have no effect on the other planets and so on. It would be a sort of perfectly amusing question for after-dinner gossip, but not really for serious consideration.

**ROGER BINGHAM:** Do other people come up to you and say, sin of pride here? Is this hubristic? How could you possibly say these things?

**ATKINS:** Well, it's pretty obvious, isn't it, why you say these things. Because if you're confronted by this nonsense, you say "that's nonsense." And it's certainly regrettable that some wonderful brains wasted themselves, like Aquinas and so on, considering these things when they could have been doing something more useful.

That was the nature of the times, really. Pride, yeah, but science is a set of procedures that has been identified by humanity as a way of discerning truth. And I think that humanity as a whole should take pride in the fact that it has identified a procedure. It took a lot of time to get there. It took a number of false routes.

It was once thought that getting on your knees and looking up with your hands clasped was one way of doing it. Didn't turn out to be very effective. It once thought that sitting around gossiping to other people was a way of doing it. That didn't turn out to be very effective.

What people like Galileo did was to go and say look, this is a way of doing it. Going out, doing experiments, thinking about them, rendering them mathematical, testing those ideas, using those ideas as bridgeheads for moving out into further regions of ignorance, and conquering, if you like, ignorance, and doing this in an extraordinarily public way.

It's a combination of the experimental method and publicly sharing results so that everyone can test them. Those two really prongs of the scientific method, pretty obvious, really. But it's proving to be a way of discovering the truth.

We humanity, not just we scientists, but we humanity should be proud that we have discovered this rather obvious approach to understanding the world. That's not evil pride; that's not arrogance. It's justifiable pride, like just being proud of your child.

**ROGER BINGHAM:** Well, now, you've been married and you have a child, right?

**ATKINS:** Yeah.

**ROGER BINGHAM:** You have a daughter.

**ATKINS:** Yeah.

**ROGER BINGHAM:** Whose name is?

**ATKINS:** Juliet.

**ROGER BINGHAM:** Same as Richard Dawkins.

**ATKINS:** Yes, exactly.

**ROGER BINGHAM:** Two Juliets.

**ATKINS:** Quite so.

**ROGER BINGHAM:** Often, the point at which people start looking for meaning or despairing of the fact of extinction and the cold, the vanishing, is because they see the dissolution of relationships and so on and so forth. This has never touched you?

**ATKINS:** Oh, constantly. Perpetually. It's dogged me throughout life in the sense of the breaking of relationships, yeah. But in terms of personal annihilation, death, if that's what you're driving towards, that when one's gone, one's gone, that doesn't trouble me.

**ROGER BINGHAM:** So, but does your daughter have any religious interest at all, any views on religion?

**ATKINS:** Not in front of me, she doesn't. I don't think she does. I think she's a very cynical person, and I think I find religious belief rather incompatible with cynicism, yeah.

**ROGER BINGHAM:** So let's go back. I want to revisit for a moment the state of science education. Last year when I was back in England visiting my mother, there was an issue of the newspaper *The Observer,* which had a big article called "The New Age of Ignorance".

And basically there was a panel of five - one, two, three, four, five, six, seven well-known scientists or scientific commentators, presenters of science TV programs, and they were asked what appear on the face of it to be fairly simple questions.

Why does salt dissolve in water; why is the sky blue; roughly how old is the Earth; what happens when you turn on a light; is a clone the same as a twin; and what's the second law of thermodynamics?

**ATKINS:** Yes.

**ROGER BINGHAM:** And I think it would be generally agreed that, with very few exceptions, these people who at least should in theory have known some of the answers got some fairly appalling responses. For example, what is the second law of thermodynamics? Well, it's about the conservation of motion, I think, but I'm not sure. Well, that was not a good answer. Why does salt dissolve in water? There's some really bad answers here. There's some estimates of the age of the Earth, ranging up to 60 billion years instead of -

**ATKINS:** [Interposing] Yes, exactly.

**ROGER BINGHAM:** - Four point whatever it is. But my point is that if this is representative, then it's very hard to chide the great general public about not knowing stuff if the people who are supposed to know it don't know it either. How do we get this stuff out there?

**ATKINS:** I think the surveys were quite extraordinarily embarrassing, and I'm sure that those who took part in it, I don't think we want to name them.

**ROGER BINGHAM:** No.

**ATKINS:** Although let us refer people to *The Observer* website. I think they must be deeply embarrassed to have exposed such depths of ignorance, even though they purport to be purveyors of popular science. But what do we do about it? Yeah. I mean, you say education, education, education, of course, but all these people are highly educated people and they either weren't listening on those days or it slipped away from them.

I mean the level of scientific literacy in the general public of all countries is deplorable. I honestly don't know what to do about it other than doing what I'm currently doing, which is trying to write books that distribute things. I'm not quite sure of what kind of answer you'll hoping that I'll give, though, because these people are no longer really working scientists. Even though they are scientific commentators and run various institutions, they are no longer really at the bench. So they are general public, in a sort of way.

**ROGER BINGHAM:** Well maybe that's it. Maybe there needs to be some sort of medium where working scientists, with their enthusiasms in place, are constantly available to pass on these ideas to -

**ATKINS:** [Interposing] Yeah. One approach is to have - these are interesting questions. Each of them is a little bit tricky to answer, but each of them is something that everyone ought to know. What there ought to be, maybe, a kind of on radio, on television kind of any

question sorts of programs where people phone in - agony aunts, if you like - with questions that they phone in and ask questions of the nature that you've described.

**ROGER BINGHAM:** Now, in fact, *New Scientist* does have things like that.

**ATKINS:** Indeed it does.

**ROGER BINGHAM:** And I think -

**ATKINS:** [Interposing] But that's read by scientists, of course.

**ROGER BINGHAM:** Yeah, so perhaps we should start doing this on The Science Network. This is a good point. But also let me take your point that these are actually, even though they look like they should be simple questions, they're not. Why is the sky blue is a non-trivial question. What was your answer be to why the sky is blue?

**ATKINS:** Well, because blue light is scattered more strongly than red light, and so as the sun shines through the atmosphere the blue light is scattered down to us. So when we look up, we see blue, leaving the red light to go traveling straight on. Which after all you see the red light at dusk when you look out towards the sun, because you're seeing the unscattered red light.

**ROGER BINGHAM:** All right. So why are clouds generally white or gray?

**ATKINS:** That is a much more subtle question. It's because the sky itself consists of molecules which are far apart. A cloud consists of molecules which are close together - water molecules sticking close together. So you get cooperative effects from scattering from neighboring molecules, and the range of the area that contributes to this cooperative scattering depends upon the wavelength of the light.

So blue light, which has a very short wavelength, the cooperating molecules are spread over a small area. Red light, which has a longer wavelength than blue light, the cooperating molecules are spread over a greater area; there are more of them. And so the two effects cancel, so although blue light is scattered more than red light, there are more molecules in the region that scatters the red light, and so the two effects cancel and the blue and the red light and all the intermediate colors are scattered effectively to the same extent, so the white light bounces into our eyes as white light. That would be my answer, had the newspaper telephoned me.

**ROGER BINGHAM:** I think they would probably take it as the correct answer. What were your most important mistakes, and what did you

learn from them?

**ATKINS:** When you asked a similar question to Dan Dennett at this table he gave the best possible reply, which was it would be a mistake to answer that question. But I wonder if it's possible to - of course there's a whole lot of personal mistakes that I'm not interested in exposing to you. Scientific mistakes? It's very hard to identify a kind of procedural mistake.

**ROGER BINGHAM:** I meant on the grounds that if the whole process of science is involved, just really having a crack at something, it's a hypothesis, test it and so on, sometimes you obviously learn a great deal from an error.

**ATKINS:** Well, I've wasted a lot of time doing calculations that didn't work. But I can't tell you what those are now, because it's far too - first of all, I've forgotten. Second, it would be too technical to do that sort of thing. But it is certainly the case that one struggles and wastes a huge amount of time, and gives up the problem. But sometimes, you realize that you really have learned a great deal from it. Mistakes are self-education, basically.

**ROGER BINGHAM:** Some thoughts on philosophy. I've heard you be pretty damning about philosophers. Is that all philosophers? Philosophy in general?

**ATKINS:** It's where philosophy is negative, where philosophy seeks to dissuade science from its ineluctable progress by suggesting that certain questions cannot be answered, by suggesting that science doesn't have the competence to discourse in a particular region of intellectual activity.

I think philosophy is quite useful in terms of clarifying ethical problems at a certain superficial level, everyday level, basically. And I think it has never, I think this is true to say, made any useful contribution to our understanding of the nature of physical reality.

Of course, one will point to philosophers who perhaps have made contributions to our understanding of physical reality, but then they were being scientists. They weren't just sitting around thinking about things and circumscribing human activity. And you get sort of destructive philosophers, as well. Social constructivists and people like that who are really undermining the integrity of the scientific method.

**ROGER BINGHAM:** So who would be your favorite one or two philosophers, given -

**ATKINS:** [Interposing] Well, Dan Dennett is clearly a wise philosopher who strides through the world examining misconceptions and doing it in a thoroughly charming way. And I have all the time in the world for him.

**ROGER BINGHAM:** Historically?

**ATKINS:** Hume, of course. Good old Dave, really, taking a cynical, skeptical eye to the fine clothes of other philosophers.

**ROGER BINGHAM:** What's the last book you read for leisure, enjoyment?

**ATKINS:** I read trash, mostly when I'm traveling and the end of a long plane journey, just can't go on any more or you're too drunk or something, or when you've got jet lag and you wake up at, you know, 11:00 at night hoping that it's really 7:00 in the morning. So I have a number of authors, mystery, that sort of thing. Detectives, adventure, that sort of thing. My three favorite authors, if you want me to name - I call them trash authors, it's far too unkind. I was using that as a kind of distinction from reading Voltaire and things like that. It would be two American and one British author. They would be Michael Connelly, who writes splendid books, John Sanford, who also writes splendid sort of detective books, the former set largely in this part of the world, Los Angeles and so on, and the latter set in the Twin Cities. And an English author, Gerald Seymour, who writes books that are based on problems that reach the newspapers, like terrorism, like the Irish problem, and so on, and do illuminate it and show the human condition, I think.

**ROGER BINGHAM:** Do you ever seek out books in which there's an attempt to use science in the book -

**ATKINS:** [Interposing] I hate science fiction, I really can't stand science fiction.

**ROGER BINGHAM:** I didn't mean science fiction. I meant fiction containing some science.

**ATKINS:** Well, the extreme of that is science fiction, of course.

**ROGER BINGHAM:** Right. But say Ian McEwan, who uses Darwinian references and so on.

**ATKINS:** Yeah, I don't really enjoy science in literature, if you like. I just like to keep the literature silly.

**ROGER BINGHAM:** Right. So what do you think about this whole notion that we started with the whole C.P. Snow two cultures thing? You don't seem to have much enthusiasm about the notion of trying to affect some sort of a marriage or at least a partnership between sciences and the arts.

**ATKINS:** Oh, absolutely contrary to that, I spend a lot of time at meetings and with colleagues discussing analogies and differences between artistic and scientific endeavor. I think it is deeply rewarding just to - and I use that expression in connection with the scientific

understanding, but it is deeply rewarding to be imbued with art in all its forms. It feeds the soul.

**ROGER BINGHAM:** Do you like music?

**ATKINS:** Oh, yeah.

**ROGER BINGHAM:** Classical music, or all forms?

**ATKINS:** Classical. I don't like much pop music, as it were. Classical music.

**ROGER BINGHAM:** The other thing I noticed is that when you gave a talk here, your PowerPoint, your slide show was about the most professional I've ever seen. It was very elegant, and I gather that you not only do all that art yourself but you also do the art that goes in these books, the illustrations and so on.

**ATKINS:** Yeah.

**ROGER BINGHAM:** How did that start? You just got into it?

**ATKINS:** Control freak. I didn't want to give up another channel of communication to an artist. I wanted my own vision to be conveyed to my readers' eyes without passing through the body of an artist. And I've become more sophisticated as time's gone on, and in a way doing the art is sometimes relaxation from word-smithing. That you've word-smithed all day, and to picture-smith for a bit is a nice relaxation mode of activity. Yeah, it's refreshing.

**ROGER BINGHAM:** But control freak, does that extend throughout your life?

**ATKINS:** Absolutely, yeah.

**ROGER BINGHAM:** Who's the smartest person you know, and who's the wisest, and what's the difference?

**ATKINS:** Oh, the smartest person I know is dead. I'm thinking of a colleague of mine in Oxford, who died four or five years ago, who you could talk to him about anything and he could make interesting comments on just about anything. He was totally ineffectually producing anything, so he was a kind of court jester, basically, in my college. But it was always a pleasure to talk to him. One knows that one could have a penetrating discussion with him on just about anything. He made most of it up, of course, but he was smart enough to do that.

Wisest, I'm going to say Dan Dennett. I think Dan is a seriously good friend. You have an interview with him in this series, and if people want to see why I think he's perhaps not the wisest person but he's up on that

ring of paradise, simply go to that interview and you'll see why. I think it's an extraordinary display of broad wisdom.

**ROGER BINGHAM:** There's a comment by Lewis Thomas that I mention quite often. He just had a little line in *Late Night Thoughts on Mahler's Ninth Symphony,* I think it was. This great line where he said, "The capacity to blunder slightly is the real marvel of DNA. Without this special attribute, we would still be anaerobic bacteria."

**ATKINS:** Absolutely.

**ROGER BINGHAM:** "And there would be no music."

**ATKINS:** Yeah.

**ROGER BINGHAM:** This is what I was talking about in terms of the capacity to bring together scientific concepts and sort of some literary. It seems to me that that was an extraordinary sentence.

**ATKINS:** Yes. Rather wonderful sentence.

**ROGER BINGHAM:** [Unintelligible] and there would be no music.

**ATKINS:** Yes, right, yes. It's certainly the case that I'm glad to be alive after Mozart. I wouldn't really wish to have been alive before Mozart, although of course I wouldn't have known that Mozart was missing. And after penicillin.

**ROGER BINGHAM:** Yeah, right. One last thought here. Again, this is from *Galileo's Finger*. Your chapter eight on cosmology, the globalization of reality, I want to go back to this point that I made earlier; we didn't fully cover that, I think.

"Science is often considered to be arrogant in abrogating to itself in the eyes of some, my own included. They claim to be the sole route to true, complete, and perfect knowledge, yet some of its greatest achievements are extraordinarily humbling. Nowhere is this achievement so majestic in this abject, humbling, appropriate, so complete as in its role in putting man in his place in the world." Would you just like to gloss that a little bit for me?

**ATKINS:** Mm. Well, the pride we've just touched on already, the pride of being able to discover a method of discovering truth, the humbling is the nature of the truth that we thereby discover, in particular the fact that we are not the center of the universe. That the universe was not designed for our comfort or more reasonably, our discomfort, if you look at it with a more cynical eye.

So everything we discover, cosmologically, really diminishes our place progressively. Our centrality in the universe, in the sense that first of all,

the Earth was the center, then it was shoved off to orbit the Sun. Then the Sun was really shoved off to the edge of our galaxy. The galaxy is not particularly special, certainly not central in any way. Even the universe itself might simply be just one of an infinite number of other universes.

So our pettiness is increasing and so in that sense, we are being progressively humiliated. But at the same time, we are discovering that we are being progressively humiliated, and I think that's an extraordinary ability in which we should take pride.

**ROGER BINGHAM:** I think that's the point that has a lot of people disturbed, though. It's a huge operation, we don't know exactly when it began; we don't know how it will end. We know something of what's going on in the interim. Don't you ever - I'm thinking now of Philip Larkin's poem, "Aubade", where he's waking up in the middle of the night or early in the morning and has just gone through this chilling realization of how finite things are. Do you ever get gripped by these kind of chills?

**ATKINS:** Well, it's how infinite things are, not how finite things are. Do I get gripped by these chills? No, I'm quite content to be petrified, to be a part of this extraordinary cosmic thing. The fact that I am not the master of it doesn't trouble me. The fact that I'm a miniscule, ephemeral component of it, an infinitesimal, literally, almost, infinitesimal part of it doesn't - I can't see why people should be troubled by that.

I think awe can stultify. I think awe is a dangerous thing, and so I would not wish to say that I am simply in awe of the universe, because that wouldn't encourage me to move through it. So I think awe is dangerous. But the difference between religion and science is that basically if the expectation of understanding, of comprehending, that religion says that that will come only after you're dead, which seems to me to be mis-selling a product.

Whereas science gives you the hope and in some cases the expectation of understanding this side of the grave, which I think is an honest marketing procedure.

**ROGER BINGHAM:** Peter Atkins, thank you very much.

**ATKINS:** My pleasure.