<u>In our Time</u> Programme 54
Time

Melvyn Bragg : Hello, at the end of the last century, HG Wells imagined travelling through time in "The Time Machine", the palpitation of night and day merged into one continuous granus. "The sky took on a wonderful deepness of blue, a splendid luminous colour, like that of early twilight the jerking sun became a streak of fire, a brilliant arch in space". When he was writing, we thought time was unbending and universal and counted out by Newton's clock. A 100 years later we have Einstein and Relativity, Quantum Theory and atomic clocks. But as we stand on the cusp of the third millennium, is mankind any closer to understanding what time really is?

With me is the theoretical physicist Dr Neil Johnson from the Clarendon Laboratory at Oxford University. He's this years Royal Institution Christmas Lecturer on the subject of time. I'm also joined by the cosmologist, Lee Smolin, Professor of Physics at Pennsylvania State University, who's currently on a years sabbatical at Imperial College. He's the author of "The Life of the Cosmos".

Neil Johnson, what's the best way of characterising Newtonian time?

Neil Johnson : It's really a clock in the sky for all to see. Very much like in the birth of the railroad, when there was one clock in the centre of the station which set the time for the town in which the station was. It was a universal time. The Newton idea is that there is a clock in the sky for everybody in the universe to see. Everybody agrees on that time, no matter how far they are away, and no matter how....what they are doing at a particular moment, when they look at the clock.

Melvyn Bragg : So the big clock's in the sky, it's regulating life on Earth, but is it independent of it?

Neil Johnson : Yes, yes, the idea is that it doesn't matter whether you're sitting down, you're travelling around in a bus, or you're in the starship enterprise, the time is the same for everybody.

Melvyn Bragg : What was time like, as it were, before Newton arrived?

Neil Johnson : In terms of how bodies and objects moved through time, that was of course a mystery until Newton came along. People weren't sure when they looked up at the sky whether the planets moved by themselves or there was some big hand behind, trying....moving them along and while they were asleep it would put the sun down and put the moon up and bring the sun back the next day, and of course, what Newton did was show that actually objects did move in a very precise way, as this thing called "time" progressed.

Melvyn Bragg : Lee Smolin, people would say that they think intuitively about time, that Newton's clock as described by Neil Johnson, which came and set up this system was something that people...in ordinary people in their daily lives was knocking around. They saw their heart beat, they can see...they knew something was beating there. They saw children grow older, tress -leaves fall off, that sort of thing. Do you think that there is that intuition now?

Lee Smolin : We have an intuition of time, and if you think about it, there are different pieces of it. I mean we have an intuition of causality, that things are the cause of things in the future. We have an intuition of irreversibility, which is very central to us as living things that the second law of thermodynamics, the idea that things decay when left to themselves, but other kinds of things, like living things, tend to organise themselves in time, and we also have an intuition of a completely different kind of time, when we throw a ball and we watch it fly, and one of the questions for science today is which of these notions of time is really the deep one? Is there one which is behind all the others, which the others are consequences of? Is there any notion of time at all? When we get down to things is time perhaps just an illusion? And the squaring....see one of the things that makes physics so wonderful as a thing to do, is confronting one's intuition with evidence from experiment and with thinkers of the past, and having the possibility of changing one's intuition. I don't think that intuition is a thing which we're born into. There was a very different intuition of time, 500 years ago. Under Newton there was a changed intuition of time. Anybody who wants to, I think can learn relativity theory and your intuition about time genuinely changes. You undergo a transformation. You're a different person, when you know relativity theory, which is something I'd recommend to everybody, is...not only for that but to have the experience that intuition is not a fixed thing, it can change, you can educate it.

Melvyn Bragg : Can you tell us, Neil Johnson, how Newton's idea, which was radical and regarded in his day as defining, and has defined a great deal of what we know about the world, and still does, can you tells us how radically that what shaken up by Einstein at the beginning of this century?

Neil Johnson : Einstein proposed two things, really quite innocuous when you hear them. One is that, just like on a train, if you're sitting on a train at the station you momentarily kind of nod off, you wake up and the only thing you can see is another train next to you and it's moving with respect to you, and in that split second, you can't tell whether you're moving or whether it's the train next to you, and it's the idea that , well actually, all you can say is "I'm moving *relative* to something else". So that was the first idea, that saying that actually, all the laws of physics are the same no matter how you're moving, it's the same, there's no particular special speed or reference in the universe. In other words, I mean that's how, you know an air hostess can serve coffee on a plane, she doesn't have to correct for the speed of the plane, she just pours the coffee, because the laws of physics are exactly the same . So that's the first idea. That's not so hard to swallow.

The second idea is slightly harder, and that is the idea that -which again we go by experiment - is the idea that unlike any...anything else, speed of light is constant for whoever observes it, and it's the same value. So okay let me just explain what that means. I mean, normally if you're...you know if somebody throws a cricket ball at you, and you're stationary, you feel a certain hit in your hands as you're....as it hits you. If you're running away from it, the cricket ball reaches you at an actually slower relative speed, so it hurts less when you catch it. If you run away faster than the cricket ball - I personally can't do that - but if you did, the cricket ball would never...it wouldn't actually catch up with you. So in that sense, the cricket ball is.....changes it's speed relative to what you're actually doing.

Now light doesn't do that, it doesn't matter how fast you run, you will always measure the speed of light to be exactly the same. Now how on Earth did Einstein arrive at this conclusion. what he did, he - so the story goes - he imagined himself looking into a mirror, as he approached, and going faster and faster trying to catch up with light. What would the image in the mirror look like? Because if light's like the cricket ball, of course, if he's *going* at the speed of light, the light will never actually leave his face, hit the mirror and get back to him, so his image will actually disappear.

But we've already said that well, there's no special...there's no way of telling whether you are moving or somebody else is moving, so if his image disappeared, he would be able to tell that he was moving and that somebody else wouldn't. He'd just make a telephone call back and say "Well my image has disappeared", and that breaks then, the first postulate, it goes against the first one. So combine those two things together, and suddenly all....you know the heavens open, the notions of time change.

Melvyn Bragg : Can you just take that on, Lee Smolin?

Lee Smolin : I think the key....one way to put the change is that as you were saying before, Newton's notion of time was what we call an "absolute" notion. As Einstein went deeper into the subject a complete repudiation of that notion of time in favour of what we call the "relational" view. The relational view is that time is nothing but an aspect of relationship between events, and any observer may carry any clock, and one can talk about a relationship between when something happens and the hand on a clock, where you are , but there's no way , without knowing a great deal more, there's no in principle reason why your clock should read the same as somebody else's clock. If we go away and we meet again, sometime in the next millennium, we...our clocks if they really accurate, will disagree, because we've moved and come apart, and that's the general case. The general case is that time is really just a measure of relationships and nothing else. There is nothing.....another way to put this is that there is a kind of **mystical side to physics** in which sometimes I think we're looking for the reality behind the appearances of life, and in Newton's kind of physics, the reality behind the appearances was something fixed and absolute and eternal, and from Einstein onward, if there is a reality behind the appearances, it's a network of relationships to all the other appearances, of all the other observers, with nothing fixed and solid.

Melvyn Bragg : Why do you think that the question of time is such a big question, intellectually?

Lee Smolin : It's the hardest question, and time is something we experience so immediately and at the same time, it's so difficult to get at what its true nature is. The idea we have of time is also changing drastically as we speak. We live in a moment where one of the key scientific questions, which involves the unification of quantum theory and relativity and cosmology, is centred on time. The question of what time is, is the key point which is at stake in trying to, if you like finish 20th century physics, which we only have a few hours left to finish! (Mel chuckles) Which means that it's one of the very deep mysteries.

Melvyn Bragg : When Newton put the clock in the sky and it's a great simplification, but both of you seem to go along with this, so that's fine by me, it set of a great train of things, we know that the inventions, the whole civilisation in the sense of physics and engineering which grew out of that, fine.
What has grown out of this different idea of time, as Lee Smolin and you have explained it, Neil Johnson? What...how does it spread into the lives we're leading? What is the fourth dimension? Einstein said that time was a fourth dimension. How do we conceptualise it?

Neil Johnson : I don't think we do. We do see effects, or relativistic effects around us. We use them in satellite...we have to acknowledge that they exist for satellite communications, global positioning system etcetera. But we don't...this is what makes it so hard to actually accept that this could possibly happen, is because we don't see this everyday. It doesn't matter how fast our bus is going, or our train is going....

Melvyn Bragg : Lee Smolin wants to come in.

Lee Smolin : Well can I disagree a little bit with that?

Neil Johnson : Well, sure!

Lee Smolin : Because I think that there are broad implications of these things. I don't think it's an accident, and I've discussed this with various legal scholars, and philosophers, that the systems of government that people invented in the period just after Newton, bore a lot of relationship to the Newtonian cosmos. There was a notion that there were absolute principles of justice, that individuals have rights which were defined with respect to those fixed absolute principles, behind what was....whatever was going on in the society. The individuals enter and have rights with respect to this fixed absolute background in the same way that in a Newtonian Universe, particles appear and have properties defined with respect to this clock in the universe and some sticks to measure things.
In the Einsteinian Universe and the Quantum Universe, as we're developing it, and if I can say I think one reason we may not have felt the implications of this, is that the process is not over. We are still in the midst, even the scientific community, and certainly the philosophers, of digesting the implications of this. I don't think that the broader society has yet to really digest this , but I think the implication is that we live in a world which is constructed by us, as a network of relationships. I think this has great implications for the problem of "what is really a democracy?", and its interesting that you see, in the writings of various legal scholars, first of all an interest in cosmology and relativity, and second you see that they're working out the same puzzle. If there is no absolute fixed unchanging eternal background, which provides the principles and provides the rights....

Melvyn Bragg : The Godlike clock?

Lee Smolin : ...yes, then how do we make a democracy?And how do we make a democracy - and for us Americans this is a key problem - how do we -and I think it is also for you here - how do we make a democracy in a pluralistic society?

Melvyn Bragg : How do you plug into that Neil Johnson?

Neil Johnson : Errrrm, I would go in another direction and say actually, time needs the quantum side of things to be sorted out.

Lee Smolin : Yes, here, here!

Neil Johnson : Now, (laughs) right, okay so....

Melvyn Bragg : Can you unravel that, before you go onto the next...... ?

Neil Johnson : Right, okay, we were....

Melvyn Bragg : Just that one sentence "Time needs the quantum side of things to be sorted out".

Neil Johnson : Side of things....we're talking really about things that started 100 years ago. These effects of relativity, that Einstein's so famous for, are one side of things. But of course, he won his Nobel prize for something completely different, which was something to do with quantum physics, which is not related, it maybe related in the future, but it's not related immediately to the very long times that we're talking about for cosmological properties, it's related to very, very short times, related to what electrons do inside atoms, and of course, eventually what things do inside the nucleus of the atom, but let's just keep it on the scale of, you know, we're made of atoms, everything's made of atoms, these atoms contain negative charges called electrons and they zip around all over the place very very fast, but they don't zip around like billiard balls or cricket balls, they're actually....they live in this very strange, kind of undecided world of being partly a particle and partly a wave . This, actually was something that, as I said, Einstein won the Nobel prize for it, but didn't like, in some sense the monster he created, because he couldn't...he didn't accept this indeterminacy at a fundamental level in nature.

Melvyn Bragg : Isn't it true that the problem that physicists have with relativity now is, is that it accounts for time and space, but it's failed to produce a picture of the world that accounts for atoms, particles and electromagnetic fields? Is there something called.....? Roger Penrose talks about for instance..."the missing physics" .

Neil Johnson : Yes, the discussions of relativity, and space and time, black holes, worm holes etcetera as set up by Einstein have nothing, no notion of the quantum world, the very small world, the microscopic world of atoms. What goes on inside an atom? What goes on inside every atom inside us is that there is quantum science, quantum physics, and in that world, time again takes on a very strange aspect, that scientists are beginning to understand, and we don't yet understand how the time within the quantum world, within this decoherence time connects the time in our world, which is outside the decoherence time. We don't understand what really making a measurement on a quantum particle actually means.

Melvyn Bragg : Lee Smolin?

Lee Smolin : Yes I think that it's very wrong to think that 20th century physics is over, and that we have as a result, relativity and quantum mechanics. 20th century physics is under construction, and relativity and quantum mechanics and the expanding universe are different aspects of something, and we're still putting these things together, and this is the great adventure. This is the greatest adventure, I think, of physical science at the moment, is combining these things. It affects our deepest conceptions, it challenges our most intuitive ideas.

Melvyn Bragg : There's a view held by some physicists, perhaps I can cite Julian Barber as one, which coincides with the view of Parminedes in the 5th century BC. Parminedes claimed that time was a figment of the imagination, and Julian Barber's gone some way - your nodding, thank goodness I got it right - to confirming that. Now what purchase do you have on that Neil Johnson, and where does it take you?

Neil Johnson : Well on a mathematical level, I can see roughly what he's talking about, in the sense that if we decided to call time something that appears in an equation, and it doesn't appear in an equation, then maybe there is no time, I mean that's a very simplified view of it, but it all comes down to "What do you actually mean by time?". Is time as Einstein said, that which is measured by clocks, if so what kind of clocks? We are in some sense a clock as well. But the trouble is we don't all agree, and our own, our clock disagrees with itself at times. So I can see on the one hand, that it has some element of mathematical truth in it, but I don't think it gets to the heart of the issue of time, and it certainly doesn't answer for me, these questions of the quantum regime.

Melvyn Bragg : Lee Smolin?

Lee Smolin : Well, I think that Julian Barber's ideas might be true, which for me is very scary. By the way he's been enormously influential on me and many other theoretical physicists on understanding the implications of relativity and quantum mechanics on the notion of time, and he has noticed that the equations of quantum gravity, that is a theory that comes from trying to put relativity and quantum theory together, do lead to this picture in which time disappears and time turns out just top have been an illusion. So he might be right, and for me that's profoundly unsettling, I hope that it's wrong. I personally work on another version of quantum gravity, motivated primarily by the hope that Julian is wrong, and really time and especially causality is fundamental in the construction of nature and I think the only honest thing to say at this moment, is this is what's at stake when we are done making this theory, we will have a notion of time which may range all the way from Parminedes, if Julian Barber is right, to a very Brooksonian, almost biological view of time, if other people are right , and at the moment the jury is out, because this is science in progress.

Melvyn Bragg : So what are the implications of time being just a figment as Parminedes said or as an illusion as you said?

Lee Smolin : If he's right, it means that the world is a collection of moments who's coherence is not total, who's coherence is in a certain sense accidental, and it will be another aspect of our world in which things that are so central to our intuition seem to disappear in a description of it at a fundamental level.

I really hope it's wrong, and I'm really....I think it's fascinating that we're discussing this, that is that these different notions of time have been proposed by different philosophers, for centuries, probably for millennia and we live in the period in which this is going to be decided. When we are done constructing the quantum theory of gravity, only one of these notions of time will turn out to be right.

Melvyn Bragg : Is the relevance of your work in the Clarendon Lab, Neil Johnson, will that help to clarify and take this discussion forward? As I understand it, you've created twins, the same particle exists in two places simultaneously , now, how is that possible and how does that relate to the conception of time?

Neil Johnson : I think this is the fundamental issue actually. We're now going from talking about things in the cosmos etcetera, down to essentially real things in labs in...to do with real....I mean, atoms that you can control. It comes back to the issue I talked about earlier, we separated from the quantum...the spookier side of the quantum world, which Einstein always rejected, by something called "a decoherence time". Now what does that mean? Particles, fundamental particles, atoms, electrons, whatever, if you capture them in a quick enough time and start letting them get close to each other and actually what's called "interfere" or "entangle" with each other, they live in a essentially, a superposition of all possible worlds. All things that could happen, are happening at the same time . It's only when you make a measurement on these atoms that they collapse -the wave function collapses, or the system chooses randomly one of the possible realities. What that says about time if we go back to the simple idea of a particle can be doing two things at once, it gives a fuzziness to what we call "now". Of course it's not the "now" that we perceive, because nothing in us is going fast enough to be able to get inside that time barrier, that decoherence time barrier. However, it's a now that's relevant for, for example, I mean if all possible things are going on, you can imagine building very fast computers out of this, something called the quantum computer . Well a very small quantum computer's already been built and shown to work. You can do things that in our real world seem impossible. I mean there's quantum cryptography , unbreakable secret codes, teleportation , the idea of transferring information from one point to another. All of these things are possible, and the experiments are actually being done, and that's what I find extremely exciting, and that's going to shed light on really the...this...this time barrier that separates us from actually the natural world, which is actually going on inside us all the time.

Melvyn Bragg : What do you think of this approximation to teleportation, Lee Smolin?

Lee Smolin : I think these things are fantastic and I think that what they're telling us is that the quantum world is really best understood as not a description of things that are, which is a very Newtonian way but as a description of processes in which information is somehow transmitted, but it is weird, and it's very humbling to try to contemplate what these things mean.

Melvyn Bragg : Well I feel very humble just trying to keep up with you two, but that's another matter! Can I ask, coming into the final stretch, some real brutally obvious questions, or one? Is it possible to think of time having a beginning and an end? First Lee Smolin.

Lee Smolin : That's a very good question. I find it very difficult to conceive of time having a beginning or an end, but at the very least the question has changed by what we were saying, because there no longer is that clock and let's be quite true about that, that clock for the whole universe out there is gone, it's a fantasy, and therefore it's not a question of time in the sense of that universal absolute time, beginning and ending, there are many times, because there are many histories and many observers, and then the question is more interesting, because certainly any time, any one of those may have a beginning and an end, and so we can have universes where time may end in some places and not end in other places.

Melvyn Bragg : Do you think time has a beginning and an end?

Neil Johnson : Errm, I think it's too soon to tell, but once you underestimate the problem that's involved, I mean it's like coming in after a you know, party and finding the glowing embers of the fire, and trying to work out if there was a party, how many people were there, and what time they arrived. I mean you just can't do it, you're working backwards, and you....I mean equally difficult is the end of time, actually the end of time I could see a little bit more easily, because we know as Lee mentioned earlier, this idea that the second law of thermodynamics which basically says that everything's...eggs break, everything gets more and more disordered, ultimately if everything is very, very disordered in the universe, by that I mean everything is broken up. If there's nothing happening, then in some sense time will have stopped.

I mean there are an enormous number of theories about what will happen in the future, but that I could kind of buy as well. Erm the beginning of time I actually have a little bit more, probably a little bit more of a problem with.

Melvyn Bragg : But do you think in the next millennium, Lee, you really do think that there will be a decision? It will be made, and we will know about time, something we don't know now?

Neil Johnson : I think...yes, and I think it will come soon. This is a fantastic period for the observation..the growth in how far back we see the history of the universe, and the discovery that the universe is not eternal, that the universe that we live in, seems to have been created, at least the part we live in, in an event which is very recent , on the scale of biological evolution or geological evolution, the universe is only 3 or 4 times older than the Earth itself, than life on the Earth, than life has been on the Earth, and so we realise that everything that we see around us, the stars, the planets, has been created by processes that we see happening as we look back in time, and the observations of this are getting better and better by the year. So there's this complete change from seeing the universe as something that's eternal and always been there, to something that we see having been created. I think this is a fantastic moment to be living in. We are just at the cusp of something and it's going to be a lot of fun.

Melvyn Bragg : Well Lee Smolin, Neil Johnson, thank you very much, and thank you for listening to us, this year, this century (laughs), this millennium. See you next century, somebody's got to say it!