SOME THOUGHTS ON TIME

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Part 1

Good Morning everybody, you will have to forgive my voice I've got a bad cold, and I hope that you can hear me. Just to give me an idea, before we start, of where you're all coming from it would be helpful for me to have a rough idea of what discipline you have come to Reading to study. So how many of you have come to study social sciences of one sort or another? Hands up if you are coming to study social sciences, economics, business studies all that kind of thing. One of you, right – two of you. How many people have come to study an Arts subject, English or History or Languages whatever? A couple of you, right. How many people are here to study Life Sciences, Biology, Botany and so on? A few, right. How many of you are here to study Physical Sciences, Chemistry, Physics, Engineering or Electronics or whatever? OK. That gives me an idea, it gives me an impression that an awful lot of you have not come to study anything at all!

My background is as a physicist, and I have been in the Department of Meteorology for more years than I care to count. One of my interests has been to understand the earth's atmosphere as one of a whole series of different atmospheres that we see on the different planets in our solar system. And that inevitably leads me to reflect on how those atmospheres formed, how the planets formed, the way they have evolved over time. And hence this talk, which pulls together various ideas from physical science, from the life sciences about time, and ends up with a few reflections on time, from a personal point of view.

Let's start off with our physicist's view of time. The physicist believes that the universe began some 13.7 billion years ago, and it began with everything squashed into an infinitely small, infinitely dense, infinitely energetic tiny blob, the so-called big bang. This picture is utterly misleading. You can see the big bang there and it is as if it is surrounded by empty space, you must realise that that little blob contains all space and time. There is nothing outside it, it's everything that there is. But matter as an energy is incredibly concentrated. And the blob expanded. It expanded over the first few seconds and then it expanded more and more slowly. Then changes took place as it expanded. After about 6 seconds the particles smashing into one another, continually disintegrating, firing off photons of electromagnetic energy, photons colliding and forming particles. At around 6 seconds, that process, the universe had expanded to the point where that process had – the energy had reduced and it was possible for particles actually to survive a measurable time. And so protons and neutrons began to form. It turns out that neutrons are unstable, the protons are stable, and that first few seconds of the universe fixed the ratio of protons to neutrons in the universe, it's about 6 protons for every neutron. That state is no matter that we understand, everything is – tiny particles colliding with enormous energy, disintegrated and reforming into different particles. As the universe expands it becomes cooler and less dense.

A critical stage in the development of the universe happened about 360,000 years after the initial start, and that's when the universe became transparent, so that radiation could pass through it instead of continually colliding with things. And we saw the great separation then between electro-magnetic energy, energy carried by light waves and radio waves and so on and matter, and the protons and the neutrons and so on.

Part 2

After the first few million years, the matter was spread out, it wasn't quite spread uniformly. There were slight fluctuations in the density of the matter and, if the fluctuation was large enough, more than about 100 light years across – a distance called the 'genes length' – then the matter could start collapsing under its own gravitational attraction and it formed objects like this called globular clusters. Collapsed into – the individual lumps collapsed into smaller lumps called stars, and so our universe contained the first stars, clustering together in these globular clusters.

And as more and more of these formed so the globular clusters themselves, amalgamated to form galaxies, the sort of galaxies we see populating the universe today. Now those very ancient stars were mostly very massive stars, extremely hot, and they were extremely shortlived. The bigger a star is the faster it consumes its nuclear fuel and the faster it goes through its lifetime. What happens is that the star is consuming the hydrogen and helium of which it is made, converts them into heavier elements. There is a limit to that process and when the source of energy, the fuel, runs out, the star collapses in on itself and at the same time its outer layers get thrown off. And in that way the earliest stars collapsed, threw off their outsides, and enriched the universe with heavier elements. To start with we had had nothing but hydrogen and helium and tiny, tiny amounts of slightly heavier elements like virilium and so on . When the death of the first stars occurred carbon and oxygen and nitrogen and elements like that started to enter the story.

We are now a few million years after the initial 'big bang'. The first, of those massive stars have gone through their lifetime, the galaxies are starting to form. The dark dust that you can see here, much of that is made up of the remnants of early stars that blew themselves to pieces. Gas clouds of hydrogen and other elements which will in turn collapse to form second generation stars.

Let's get a bit closer to home. Our own sun formed between 4 and a half and 5 thousand billion years ago. It formed as a third generation star that is to say that the material of which it is made has formed stars, collapsed and been blown out again at least twice before our own sun formed. So as well as hydrogen and helium, it contains significant quantities of heavier elements like carbon, and oxygen, and nitrogen, and metals such as iron and calcium, and so on.

Our own sun, is just about the most standard and average star you could expect to find. It's what we call a 'yellow dwarf', its total lifetime is about 12 billion years, so it formed 4 and a half billion years ago, it's something like, just a bit less than half way through its lifetime, as present. It actually sits near, near the - about two thirds of the way out in its galaxy - this is not our galaxy, it is the Andromeda galaxy but if we transpose the sun, it sits something like there, out in the periphery of the galaxy, well out of the violent events of the galactic centre.

Part 3

So the early sun condensed out of a cloud of gas which contains heavier elements as well as hydrogen and helium. Not all the gas condensed into the sun, quite a lot of it formed a disc, a spinning disc of material surrounding the sun. From that disc the very earliest precursors of the planets formed. What happened was that material gradually stuck together to form little stones at first and then bigger boulders and then gradually small planet-sized bodies. This shows a computer simulation of what it must have been like. There's the sun in the centre, and here we have a great cloud, in this case we have put in 100, we call them planetesimals, precursors of planets, small bodies but smaller than the planets we see now, and you can see they are all over the place. And their orbits criss-cross as they go round the sun. What happened in the early solar system was that these various planetesimals quite frequently, would collide with one another. The small ones would be smashed to pieces, the big ones would gradually grow as they accreted, more materials from the small planetesimals.

And so after 30 million year or so of this process our original 100 planetesimals have coalesced into 22 larger planetesimals. You will see that their orbits are still quite chaotic, they still cross one another, and so collisions are still happening, but they're happening more infrequently, but having said that, when they do happen, they are much more violent because they are much bigger objects that collide with one another. In this particular computer simulation after 440 million years we end up with just 4 major planets. Now because the number of planets has gone down, because every time you have a collision you modify the orbits of the planets, you can see now that the orbits no longer cross one another so collisions are now much, much less likely. These are relatively long-lived things. These are the sort of planets that make up our own solar system. I say this is only a computer simulation, it is not necessarily the way our particular solar system went, it's the way a solar system might go. Our own solar system has ended up with 8 or 9 major planets and a host of smaller bodies, particularly further out in the solar system.

But all this happened quite soon after the initial formation of the sun. By 4,000 million years ago, the solar system existed in essentially the form we see today, with the planets we see today and the sun that we see today. We understand the earth itself of course was built up in this way by continual collisions gradually building up a body. In its own history it had one particularly violent and catastrophic event which is illustrated here. There is the young earth, it's shown green, it wasn't really green, it's just to differentiate it, and it was struck, by a planet about the size of Mars. It was struck obliquely in its northern hemisphere. That did two things, the first thing it did was to knock the rotation axis of the earth through an angle. So our rotation axis now is something like 23 degrees to the plane of the orbit, and that is why we have seasons.

And at the same time the glancing collision increased the rotation rate of the earth, so the earth started spinning much more rapidly. That collision was really violent, these two bodies are large, and they hit at a relative speed of many kilometres per second. The energy of that collision heated both bodies - it probably completely melted the earth, liquefied what solid rock there was. And the impacting planet, well some of it got mixed up into the earth, some of it was thrown off in a cloud of fragments and particles. That cloud of debris that was thrown off from the collision, condensed to form our moon. And that is the reason why the earth is unique in the solar system in having such a large moon. It's far and away the largest moon in the solar system compared to the size of the primary planet. We can build up this picture incidentally by careful analysis of the composition of the earth and the moon. We can detect the material that came from the proto-earth and from the colliding planet.

Part 4

This is a picture of the planet Mercury as it is today. Mercury doesn't have an atmosphere and compared to the earth it's a rather inactive planet. Its surface, is a record of its entire history since it formed. And you can see it's covered in craters, little ones and big ones. Some craters have rays of material radiating out from them. This surface is a record of all those collisions that took place in the early solar system, gradually building up the planets. In the case of the earth, these bombardments have long since been eroded and wiped out by water flowing over the earth's surface, by volcanism, and so on. In Mercury none of those things have happened. We can still see that record, as we can over large parts of the moon's surface.

All that happened very, very quickly. By about as I say, 4,000 million years ago the solar system had settled down to pretty much the state that we see it now and it has changed very little since then. What we think will happen to the universe as a whole, well we think it will carry on expanding. The material in it will become colder and less dense as it expands. The bright stars that make it up at the moment will go through their life cycles, they'll run out of fuel and they will go out. They will be survived by dimmer, low mass stars which will carry on burning for a great deal longer, but eventually they too will exhaust their fuel and go out and eventually, and I am talking about billions, and billions and billions of years into the future, the universe as far as we can see will finish up cold, dark and essentially inactive.

For the physicists view of our universe, it's a bit like this. It started with events of enormous violence, and through the whole history of the universe they have gradually run down, they have become less violent. We are sitting somewhere here at the moment where there is enough going on to be exciting, but not enough to disrupt the planet every few years. And eventually we end up down here where virtually nothing goes on and it takes a very long time to go on if it does. A universe that runs down, and eventually stops, that, if you like, is the physicists view of the large scale history of the universe we live in.

Let me now take an alternative view. Let me look at our understanding of the universe, or the earth, from the perspective of a life scientist, a biologist. The biologist's story starts about 4 and a half thousand million years ago with the formation of the earth. A time of enormous violence, when the planets were continually being resurfaced as other bodies collided with them, orbits were continually changing. Things settled down, the earth settled down to a stable orbit, the bombardment rate dropped down, and an atmosphere formed so the climate became relatively stable. All this happened a mere 60 million years or so, after the formation of the earth. And as far as we can tell the first very primitive life forms appeared not very long after that. We don't know whether they evolved in place, or whether they had been introduced by bodies colliding with the earth from somewhere else in the universe. But we can tell that there were some living organisms, not very long after the earth formed.

And at first they sat there doing very, very little. This is an example of one of the primitive life forms that dominated the early earth. They are called *stromatolites,* they still survive in a few places. These were taken in a sheltered bay in Australia. And they are very, very primitive organisms, they live in colonies and they make a silica shell for themselves so that they appear as these sort of circular blobs of silica stone. They are very vulnerable of course to anything else that attacks them. But in a world where they were the only living things, then there was nothing to attack them, and so they were the dominant life form, I find the time scales fascinating. These *stramatolites* were the dominant life form for the first 3-and-a-half thousand years of earth's history. For 80 to 90% of the time that the earth has been capable of supporting life. Suppose some aliens had landed on the earth 2000 million years ago, this is all they would have found by way of living things.

Part 5

Of course it did not stay that way forever, but it did stay that way for an enormously long time. What happened was that the earth very, very gradually, changed. This diagram takes a bit of looking at because it's a wee bit on the complicated side. There is a time scale, it goes back to the beginning of the earth, 4,600 million years ago, and it goes up to about 100 million years ago. The scientists among you will recognise that this is a highly non-linear scale, it's a log scale. So the early history of the earth has all been squashed up to that end and the recent history has been expanded down here.

These stromatalites they were the dominant life form from 4000 million years ago until 1 thousand million years ago, something like that in the, what we sometimes call the Pre-Cambrian era. Now the earth at that time would have been very different from the earth we see today. There was water for sure, but the atmosphere instead of being made up mostly of nitrogen and oxygen as it is now was probably made up mostly of carbon dioxide and various other reducing gasses. Levels of oxygen in the atmosphere shown on this axis, way down a thousandth of the current levels. Hardly any oxygen – you and I could not have survived on that early earth. The stromatalites did not need much oxygen, they don't do very much, they don't have to breathe very hard, so they could survive in the same way that today, in bogs and so on, you can get aerobic bacteria that don't need oxygen to go through their lives.

Things changed very, very slowly at first but rather crucially. They changed as the blue-green algae appeared. The blue, what we call the blue-green algae, were single celled organisms, that were able to utilise sunlight to make organics molecules just as green plants do to this day. And of course one of the bi-products of that photosynthesis was that they gave off oxygen and you can see the oxygen started to increase. By a thousand million years ago the level of oxygen in the atmosphere was about 1% of what it is today.By about 500 million years ago, the end of the Cambrian period, it was close to the levels that we experience today. Some call this the greatest pollution event that has ever happened on the earth. An event in which living things on the earth's surface have transformed the composition of our atmosphere to release enormous quantities of oxygen. A highly reactive element which of course makes the sort of life forms that we are used to which consume enormous amounts of energy, makes them possible.

So 500 million years ago or so our present, what we call The Fossil Record really started. For it was about that time that the first creatures with hard shells appeared, readily fossilised creatures, crustaceans, molluscs and so on. They were followed in short form by the first bony fish, by land plants, and about 3 million years ago, 4 million years ago the first land animals and so on.

Let me just scan through that. There was one of the very early creatures that appeared suddenly in the Cambrian - as the oxygen levels went up, so there was an explosion in the variety of species present on the earth. These trilobites are a famous example whose fossils are found across the earth.

The first fish appeared, say 400 million years ago. There is a famous example the so-called coelacanth which has been discovered in deep water off Africa. It is a living fossil, it was only known from fossils about 400 million years ago until relatively recently when an example was caught, a living example was caught.

Part 6

Between 160 and 165 million years ago we had the age of the dinosaurs, reptiles became the dominant life form and some of them grew to enormous size. I always think it is very ironic that people if they want to put someone down, call them a dinosaur. Someone who is old fashioned and unsuccessful, and destined to die out. Dinosaurs were dominant life forms for about 100 million years on the earth. Human beings have been a dominant life form for, for at most 10,000 years. So who's successful? People or dinosaurs? Anyway those are dinosaurs.

Now we have one of the interesting twists that is becoming more and more apparent as we study the history of our earth. Why did the dinosaurs fail to continue their dominance? We think it was largely because of an astronomical event, a collision between the earth and a small asteroid and comet. These things still happen, they happen much less frequently than they did in the early solar system, but they do still happen. For example in 1994 Comet Schumacher-Levy impacted on the planet Jupiter. You can see there one of the big fragments of Schumacher-Levy it has just hit the surface of Jupiter and you can see concentric shock waves going out from that collision. So that comet had added a tiny bit to the mass of Jupiter.

It still happens, and it has been worked out that on the earth we collide with a significant body perhaps every 100 million years or something like that. It is not very often, but because the effects are so enormous we now recognise that it is actually a significant threat to human life. In terms of lives lost per year a collision with an asteroid would be far more damaging than hurricanes and other natural disasters. And an observatory has been set up to track bodies that could possibly collide with the earth, monitor their orbits, and check whether they are getting dangerously close, it's actually taken seriously.

So there's the end of the dinosaurs; some 65 million years ago the earth was transformed by this asteroid smashing into the earth. We think it destroyed a lot of the food supply, it probably filled the atmosphere with a huge cloud of smoke, and so for several years there was virtually no plant growth. That meant the plant eating dinosaurs starved, and that of course meant that the flesh eating dinosaurs starved. And it was left to smaller more adaptable organisms to take their place, and of course the early mammals, probably little more than tiny mice at that stage, became the dominant life forms on the earth.

In our story of the earth starting 4,500 thousand million years ago recognisably human beings appeared perhaps a million years ago. We are not quite sure when, it is a bit difficult to work out. But primitive hunter-gatherer peoples, living in small bands, 20 or 30 people.

So the biologists' picture of the way in which our earth has evolved is almost the opposite, of the physicists' picture. Over time we have huge times, thousands of millions of years, in which things were very, very inactive. Stromatalites, sitting there, being warmed by the sun, and that's about it. And in the Pre-Cambrian, the first hard bodied animals appeared and the complexity and the rate of evolution of our biology has increased ever since. And the human species is of course continuing that. The human species which appeared perhaps a million years ago, 10,000 years ago, or thereabouts, people started settling down - instead of wandering around as hunter gatherers they settled down, agriculture was started. The first towns, villages and towns, were formed, 10,000 years ago in a 4 and a half thousand million year history.

Part 7

Something enormously important had happened at about this point. Until that point information has passed from one generation of living creatures to another, almost entirely through the DNA that makes up their cells. That DNA changes only slowly, most changes don't work so most creatures die out. The few that work actually carry information from one generation to another and so evolution proceeds at a relatively slow pace, taking thousands of generations probably for creatures to evolve significantly.

With humanity a new mechanism started. With language, and later on written language, information could be passed very readily from one generation to another. What one man learned would be taught to his son, would be taught to his children, and so on. And that's what has fuelled the very rapid changes that are human societies. The passage of information by means other than handing your DNA onto the next generation. About 5,000 years ago we stopped being an oral culture and became a literary culture, language was written down. We would go to libraries and read about what previous generations thought, and something like the urban society became possible.

About 800 years ago, in Europe at any rate, an industrial society began. Big towns where they manufactured things, initially cloth and products like that. But later on of course, metal working and other industries. About 200 years ago perhaps, beginning of the 19th century, we started what you might call a technological society. The rise of the steam engine, both to power factories and as a means of locomotion, to move people around. And the latest big advance I guess, the digital electronic society which has been with us for little over 20 years, at least as it affects the mass of people. Can you see the enormous acceleration of change that is taking place there.

So that's the biological picture. Things are becoming incredibly complex, incredibly evolved in shorter and shorter times. By way of a postscript I would like us to think about our own lives. Look back over your lifetime and think what has happened to you. Some of you may have done an exercise like this. If you haven't, you might find it interesting to do it.

One version of it is what they call a life line or a time line. Draw time along there, and just draw a wiggly line recording significant events, that you can recall in your life. So here is my time line. That's when I went to school for the first time, that's perhaps when I went to secondary school, I won't tell you what all the others are. But when I look back I am not conscious of time so much as a continuous succession of events, but certain events assume dominance in my memory. When I look back at my life I remember a sequence of very big events, that had enormous significance for me. My guess is the same is true for all of you in this room. When I look back over the more recent past, of course, it is cluttered up with lots of more minor events. But as time goes past so those little events – what I had for tea yesterday, and so on start to fade into insignificance and I am left with the big things, when my child was born and things like that.

Part 8

It is interesting I think, that humanity tends to assume that everything is the same everywhere, things carry on as they are. We assume that the sort of society we live in is the normal form of society and yet it has only been around for a handful of years. We tend to assume that the world we live in, is the natural state of the world and yet we have seen this morning how 90% of the earth's history, the earth has been utterly different from what we see around us today.

And - in fact, our lives are made up of this sequence of disconnected events. And that introduces me to a third sort of time. We have had physicists' time, we have had biologists time, the third sort of time is what you might call personal time. I am going to use the Greek work '*kairos*' for it. It is time in the sense of the 'apt' time, the 'appropriate' time, the 'proper' time. For example if you see a good actor you say their skill as an actor is due to their sense of timing. Not just saying the words, but knowing just *when* to say them, how long a pause to leave for them to have maximum effect. And I'd suggest that in our personal lives this *kairos* time, the right time, the moment when things come together for us, the moment when we realise something, and do something about it, whatever, that's the time that's important for us, for us personally. And I would like to finish with a poem by a man who, in my opinion is the greatest poet writing in English of the 20th century, a man called R.S. Thomas, who was a priest in rural Wales and he wrote this poem called 'The Bright Field'.

'The Bright Field'
I have seen the sun break through
To illuminate a small field for a while,
I had gone on my way and forgotten it.
But that was the pearl of great price
The one field that had the treasure in it.
I realise now that I must give all that I have
To possess it.
Life is not hurrying on to a receding future
Nor hankering after an imagined past.
It is the turning aside, like Moses,
To the miracle of the lit bush
To a brightness that seemed as transitory as your youth, once
but is the eternity that awaits you.

Thank you.