A Teaspoon and an Open Mind:

The Science of Dr Who

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Most of us have wondered where we would go and what we would do if we had the ability to return to the past or to travel into the future. Would you want to know what is going to happen to you — who you will marry, what your kids will be like? Would you wish to return to the past and correct a mistake, unsay something you should never have said? Or alternatively, would you want to experience for yourself the Battle of Waterloo or the Kennedy assassination? Some people would instead like to see what will befall the human race, to witness what wonders and horrors lie ahead of us.

But is any of this really possible? Is time travel an idea that will always remain fantasy or is there a chance that in the distant future we might develop the technology to travel in time? Alternatively, is it feasible that there exists an advanced civilization somewhere in the universe that is even now able to master time and to travel anywhere at will?

At the moment, no one has a clear idea how of a time machine could be constructed, and physicists working at the very edge of science are only now beginning to piece together theories that may explain how time travel could be possible in some distant future. Today, these ideas exist only as mathematical concepts. In practical terms we are a very long way from building a Tardis. But, the initial step towards constructing a time machine is to understand the mathematics behind it. And before we can develop any theory of time travel we have to get to grips with the meaning of time itself.

We all experience the passing of time, but no one seems able to explain conclusively what time is. Some even suggest it is nothing more than a construct of our own minds, that we piece together events in a logical, linear order because that is the only way our brains can operate and make sense of the universe. There is no hard evidence to support this concept but, for what it's worth, we all seem to have an in-built awareness of the direction of time, a concept which has been dubbed the arrow

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of time. But, beyond this subjective perception of time, the more clinical answers provided by physics may eventually lead to a time machine.

It is a striking fact that on a sub-atomic level almost all processes in the universe can be conducted in either temporal direction. This means that if two sub-atomic particles come together and interact to form two other particles, the reverse of this process is equally viable: the two product particles could just as well interact to create the starting particles.

Yet we don't experience this reversibility in the 'real' world of our everyday existence. We don't see shattered glasses re-form, light does not leave our eyes and travel to distant objects, and the dead do not rise from their graves. Yet this seems like a contradiction, because it implies that principles governing the behaviour of 'simple' systems (those that operate on a quantum level, such as atoms) are not the same as those that determine things in our everyday lives - such as how a car moves or the motion of a billiard ball. This is weird and seems paradoxical because, after all, every material thing in the universe is made up of fundamental particles. If these particles behave reversibly on the simple atomic scale, what is it about everyday situations that seems to make them act differently?

The answer lies in the difference between something being impossible and just very unlikely. Physicists believe that it is not impossible that the dead could be made to rise again (ignoring spiritual considerations), or for a broken glass to re-form by chance; it is just that these events require so many improbable steps to interlink perfectly (at least compared to the interaction of two sub-atomic particles) that we would almost certainly have to wait for a period longer than the lifetime of the universe to see them happen naturally. This means that although they are not impossible, they are highly improbable.

Another way of putting this is to say that quite literally anything can happen, but the more unlikely it is, the longer you would have to wait to witness it. It is possible you could spontaneously transform into a jellyfish while reading this book, but it is unlikely. However, if you had many times the life span of our universe in which to read the book, there is a more significant chance that during that period you would transform into a jellyfish.

To see why this should be, we need to consider one of the most fundamental rules of the universe, a principle called the second law of thermodynamics.

This law lies at the very heart of physics, and, unlike many ideas in science, the second law of thermodynamics is actually one based entirely upon common sense. Put simply it says that 'Everything wears out', or, in more formal terms, 'The entropy of a closed system always increases'.

The word 'entropy' is the technical term describing the 'level of disorder in a system'. So, by the second law of thermodynamics, a cup of tea exhibits a higher level of entropy than the individual tea leaves, water and milk because they have been mixed together - the mixture is more disordered than the original ingredients in their separate containers. Another way of thinking about it is that it would take more

energy to separate out the ingredients of the tea and put them back in their individual containers than it took to mix them up together in the first place.

In the case of the broken glass I mentioned earlier, if we tried to bring together the pieces, like running a film backwards to re-create the glass perfectly, we would need to lower the entropy of the system. This is possible (in fact, living creatures spend most of their time attempting to produce a local lowering of entropy - just think of housework as an example), but it requires energy (in this case, more energy than it took to shatter the glass), and so the chance of this happening naturally is incredibly small.