-ROYAL COLLEGE OF SCIENCE UNION SCIENCE CHALLENGE 2014-

What does science tell us about the nature of time?

A motivator, an ally, an enemy, a threat – a perpetual reminder of the countdown to our deaths. Time dominates our lives; we simply cannot escape the relentless ticking of the clock. However, begin trying to define 'time' and you are faced with an immediate challenge; what actually *is* it? Does it exist? And, more importantly, how would we prove its existence?

First, we shall consider the components of time with which we are most familiar – the past, present, and future. You could define the 'past' as a collection of memories, and the 'future' as a projection of our lives based upon experiences in our past. Yet, beneath these seemingly simple concepts lie extensive physical and philosophical problems. For example, we cannot directly experience these phenomena; we can only consider them in the present. However, much of what we perceive of the present has already become the past - time is infinitely precise, and we process thoughts too slowly to keep up. Immediately, the 'past', 'present' and 'future' prove unreachable points in space and time. These once familiar concepts begin to appear hypothetical, a fruit of our human desire to apply chronological reasoning to our existence. To determine the true nature of time, we must open our minds to the most abstract of concepts, far beyond the boundaries of previous rationale. Einstein once wrote in a condolence letter to the sister of a friend (March 1955): "*People like us, who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion*".

So what has science discovered so far? Throughout the 20thcentury, a dominant area of interest concerned the inextricable link between space and time in the fourth dimension 'spacetime'. The malleability of this elusive material was elegantly illustrated by Einstein's theories of Special and General Relativity (proposed in 1905 and 1916 respectively), which describe time dilation in motion and in gravity. Although these hypotheses are highly intriguing, they are fundamentally useless unless supported by observable results. In the words of Richard Fenyman - "*it doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong*."

Thankfully, numerous experiments have provided results to support Einstein's theories, such as the Hafele-Keating investigation. In October 1971, two men flew caesium-beam atomic clocks twice around the world (eastward and westward) in commercial airliners, then compared them against clocks at the United States Naval Observatory. When brought together, the three clocks disagreed with each other; the differences were consistent with predictions from Einstein's equations (to approximately 10% precision). -59 ± 10 nanoseconds were gained travelling eastwards, and 273 ± 7 were gained travelling westwards. Since the Hafele and Keating's time, similar (but increasingly complex and precise) experiments have been carried out and produced supportive results; it is agreed amongst most physicists that Einstein's infamous theories have been proved (or at least strongly evidenced) since at least the

1970s. However, you cannot be certain that the next experiment, under different conditions, will not prove them wrong. If that happens, the theories must be abandoned, or revised at the least.

One of the most interesting concepts involved in our developing understanding of time is, of course, the possibility of time travel through wormholes (hypothetical tunnels through warped spacetime). If space and time are so inextricably linked, could we consciously move in time like we do in space? Before we become too absorbed in the interior design of our future Tardis, there are several problems to consider first.

The principle issue concerns the protection of cause and effect. The Grandfather paradox demonstrates this perfectly – you cannot travel back in time to kill your grandfather, otherwise you would not have been born, and therefore could not have travelled initially. Soon another problem arises; why don't we meet travellers from the future now? Some suggest light is not scattered off time travellers, but do they exist if they cannot be seen and are somehow prevented from taking actions? Multiverses would allow travellers to perform actions which would not affect their futures in original universes. However, the current theory is unconvincing – there is certainly no way of investigating the concept experimentally. As a result of this seeming infeasibility of time travel, many have discarded the idea (and boycotted Doctor Who) in favour of more logically and experimentally viable physical ideas.

Scientists are not certain of the laws of time, what makes time 'tick', or why space and time exist at all. However, we cannot lose faith. Considering time through a scientific perspective leads us to an infinite path of discovery, one we must embark upon with open minds – no theory can be discarded until is it disproved. This opportunity for boundless thinking teaches us that science is at heart a creative pursuit, and the only way we will succeed in learning more about time - and possibly manipulating it to our advantage - is by exploring every avenue, even the seemingly most ridiculous. Ultimately, that is what the best scientists have always done.

For now, the search continues.

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