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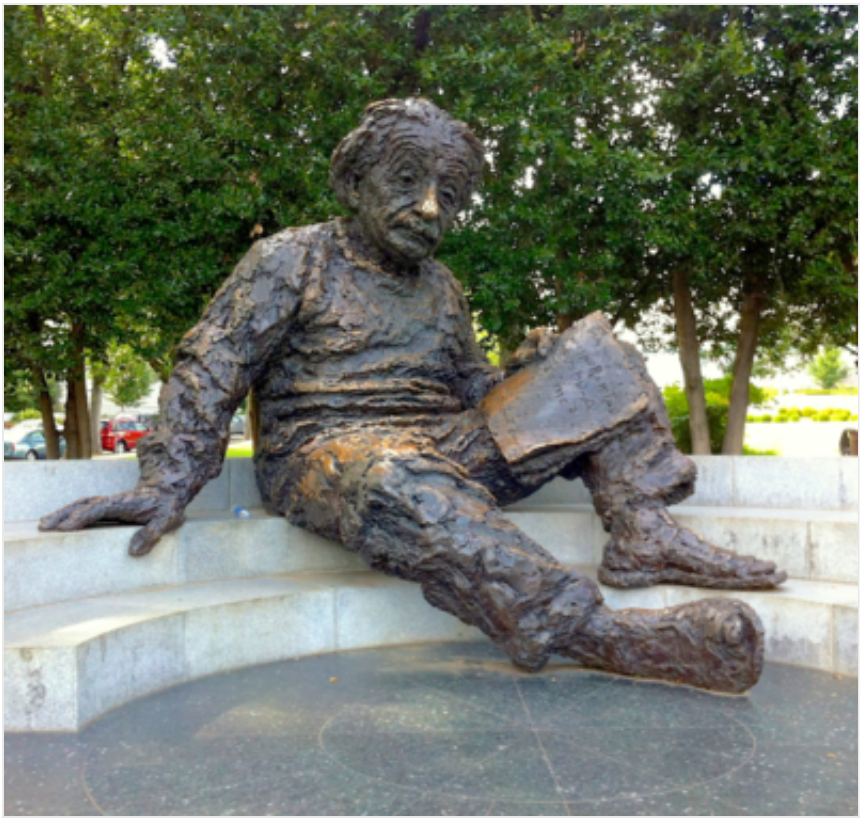
Of November Thursdays, and Monuments to Genius

by Tasneem Zehra Husain

The development of [my] thought-world is in a certain sense a continuous flight from wonder.

—Albert Einstein



We are marked in large part by our celebrations: what we celebrate, and how we choose to do so, says a lot about who we are. As a global society, we seem to be increasingly fascinated with genius, and almost sixty years after his death, Einstein continues to be emblematic of this phenomenon. Over time, he has become larger than life - more myth than man.

In the annals of physics, Einstein's footprints are everywhere; his contributions as various and scattered as if they too, were subject to the brownian motion he elucidated. Along most paths he trod, he left staggering achievements in his wake. Einstein made crucial contributions to a nascent quantum theory, his incisive explanation of the photoelectric effect was so brilliant, it won him the Nobel Prize, and yet, most physicists, if asked to name Einstein's definitive work, would unblinkingly pick general relativity.

The theory celebrates its hundredth birthday in a couple of weeks, and festivities are underway across the globe.

Over four successive Thursdays in November 1915, Einstein presented his (still developing) theory to the Prussian Academy of Sciences in Berlin. He laid down ***The Formal Foundations*** on 4 November 1915, and worked feverishly every day, polishing and honing the theory, coaxing out some of the gems that lay hidden within, until finally, on 25 November he unveiled the spectacular ***Field Equations of Gravitation***.

"Hardly anyone who truly understands it will be able to escape the charm of this theory," wrote Einstein in this final paper, and his remark has stood the test of time, just as well as his equations have. The General Theory of Relativity is a work of unparalleled beauty; in fact, it exemplifies what it means for a physical theory to be beautiful, and is often quoted as the canonical example of such.

There is an air of inevitability about general relativity, which Nobel Laureate Steven Weinberg equates with beauty. "In listening to a piece of music or hearing a sonnet one sometimes feels an intense aesthetic pleasure at the sense that nothing in the work could be changed, that there is not one note or one word that you would want to have different," he writes. It is so with general relativity. No idea or symbol seems extraneous or out of place.

A complementary aspect of beauty has to do with the intellectual pleasure we experience in encountering a concise and elegant solution to a deep and basic question. Thus far, the theory has passed every test it has been set. Time and again, we have conjectured or discovered objects and phenomena, only to find out that they lay embedded in Einsteins's equations all along. A century spent, plumbing its depths, and the theory has not yet been exhausted.

In his novel Timescape, Gregory Benford describes quite eloquently the feelings evoked by general relativity. In one of my favorite passages, he writes "there was a blithe certainty that came from first comprehending the full Einstein field equations, arabesques of Greek letters clinging tenuously to the page, a gossamer web. They seemed insubstantial when you first saw them, a string of squiggles. Yet to follow the delicate tensors as they contracted, as the superscripts paired with subscripts, collapsing mathematically into concrete classical entities - potential; mass; forces vectoring in a curved geometry - that was a sublime experience. The iron fist of the real, inside the velvet glove of airy mathematics."

General relativity caught the imagination of the public when it was just discovered, and the fascination endures to this day. From Einstein and Eddington to Hawking and Penrose, many brilliant physicists have interpreted the theory for a lay audience, and many gifted science communicators have penned their own accounts - particularly this month, to commemorate the centenary.

I could wax lyrical about the gedanken experiments that take place in sealed rooms, accelerating in deep space; I could go on about how, to an external observer, a light ray shot across the room appears to take a parabolic path downward, mimicking the familiar (terrestrial) trajectory of a stone, flung in the air. I could tell you that, since acceleration is responsible for the former observation, and gravity for the latter behavior, Einstein somehow connected the dots and equated gravity and acceleration. But all that has been done, extremely well, multiple times, so I will resist the urge to add my explanation to the pile.

Instead of belaboring the details of how he did it, I want to stress what Einstein accomplished. And what he did, according to Bertrand Russell, was to "remove the mystery from gravitation, which everybody since Newton had accepted, with a reluctant feeling, as unintelligible". When Newton wrote down his law of gravitation, he made it clear that while he could express the mathematical relationship between massive bodies and the gravitational force they exert at various distances, he could not say why it was so.

There is much to be gained by surmising the empirical rules that govern a particular behavior, but far more to be learnt by uncovering the motivations of the character. Say a crime is perpetrated. Even if you have collected all the evidence from the scene, and are in possession of all the facts, it often happens that the mystery can't be solved until you have an insight into the psychology of the suspects, and can form conjectures regarding their motivations. While Newton had a very good grasp of the mechanics, he lacked these deeper insights into the nature and motivations of gravity; a fact he made no bones about. "As to what gravity is, I leave that up to the reader," he famously said. And for several centuries, no one rose to the challenge. Until Einstein.

Einstein's true brilliance lay in shattering the illusion of gravity as a masterly force which mysteriously summons objects from across distances, and exposing it instead as an intimate and ongoing conversation between an object and the space-time in which it finds itself. There is an active interplay, a feedback loop, a call and response. "According to the general theory of relativity, the geometrical properties of space are not independent, but they are determined by matter." Einstein wrote, in Relativity, The Special and General Theory. The path taken by a material object is dictated by the shape of the surrounding space-time, which, in turn, is affected by the presence of the matter itself. Instead of being a passive background, space-time was exposed as a undulating entity, quivering in reaction to occupation.

Much has been made in recent years about the fact that Einstein's theory of gravitation is incomplete, that it does not encompass quantum phenomena, but Einstein knew that already, almost a century ago. "The theory of relativity, as I developed it originally, still does not explain atomism and the quantum phenomena", he said "And neither does it include a common mathematical formulation covering the phenomena of both the electromagnetic and gravitational fields. This demonstrates that the original formulation of the theory of relativity is not definitive . . . its means of expression are in process of evolution. . . .".

The search for quantum gravity is enthusiastically underway, and if and when we reach that so called ‘holy grail' of theoretical physics, we might have to tweak Einstein's golden theory. But such future modifications will most probably have to do with revelations about the nature of space and time at short distances, rather than the interpretation of gravity as the manifestation of a curved space-time that interacts with matter. And that latter was, at least to my mind, Einstein's true and greatest contribution.

Coming back now, to celebrations. Einstein is a global figure who transcended the bounds of space and time, and is beloved across nations and ages. His life and work is commemorated in various ways across the world - even more so this year than usual - but my personal favorite remains the tribute paid by the Einstein Memorial at the National Academy of Sciences, in Washington, D.C. Robert Berk's bronze statue conveys both the spirit of the man, and the scientific quest upon which he embarked: it is visually appealing, inviting, and fraught with secrets for those who choose to look.

Upon dedicating this memorial, on the centennial of Einstein's birth, the prominent physicist John Wheeler said: "No statue of a scientist ever erected in this country was meant to have more meaning, and has more meaning than this. How can one best symbolize that science reaches after the eternal? How else than in a monument to the man who united space and time into space-time?"

From a distance, you see Einstein, paper in hand, sitting casually on steps circumscribing an emerald pearl dais. If you come closer, you see that the paper bears the three equations which represent Einstein's trio of masterpieces: the photoelectric effect, the general theory of relativity, and the iconic mass-energy equivalence E = m2. Looking around, you notice that the steps upon which he sits are engraved with his quotations, and the dais in the center is encrusted with studs of various sizes which represent the galaxies, the planets, sun, moon, many stars and several other celestial objects, to scale: the universe is, quite literally, at Einstein's feet.

Wheeler continues "How can one most movingly say that science - and the application of science to the needs of society - is a work for the young in heart, those greatest of all ‘friends of the future?' Not by a pompous figure on a pedestal. No, a figure over which children can crawl; a figure around which young people can sit and think long, long thoughts..."

Should you respond to its unspoken invitation, and climb up on to the circular platform to engage with the statue more intimately, you will discover that no matter where you stand, Einstein's gaze is directly upon you; should you choose to speak to him, you will find that, within that radius of wonder, your words are amplified.

When I saw the statue for myself, I was struck by its parallels to the general theory of relativity. As monuments to the memory of this great scientist, both are worthy of being sculpted in stone, and yet both leave room for future generations to crawl over them. With general relativity, as with this statue, at every

successive level of engagement, curiosity is rewarded, and wonder awakened; there can be no better way to celebrate the legacy of Albert Einstein.

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