The discovery of quantum mechanics and relativity at the beginning of the twentieth century was precipitated by a succession of groundbreaking experiments. These include the Michelson-Morley experiment, the black body radiation curve, the photoelectric effect, atomic spectra, and the specific heats of solids. Both these new theories are often presented as the overthrow of the absolutism and determinism of Newton's mechanics. However, `overthrow' is too strong a view of what changed because of these beautiful experiments.

Consider time. Newton made a clear distinction between an absolute mathematical time, and time that is measured by clocks – this latter being called common time or duration. If we denote absolute time as T and common time as t, there is a profound assumption that is made: T = t. That is, clocks are assumed to be measuring absolute time whereas they only measure durations. In going over from Newton's mechanics to special relativity, what is overthrown is the Galilean invariance of the duration, thus making simultaneity of duration relative, and replacing the Galilean invariance of duration by the Lorentz invariance of the space-time interval. What does this transition to relativity do to the absolute time T? Nothing!! Does the transition imply that absolute mathematical time does not exist? No, it does not. In fact, Lorentz advocated his version of special relativity theory, empirically equivalent to Einstein's, in which absolute time is not rejected. In essence, the manifold of spacetime, labelled by the coordinates (x,t), evolves in absolute time T. At absolute time T_1 the particle is at spacetime coordinates (x_1, t_1) and at absolute time T_2 it is at spacetime coordinates (x_2, t_2). The particle evolves along the spacetime worldline in absolute time T. This absolute time is the one that flows. Coordinate time t, this being the same as duration, does not flow, nor does it keep track of past, present, and future. The philosopher Bergson debated with Einstein that philosopher's time [we prefer to call it absolute time T] was distinct from duration but was overruled by Einstein. In rejecting Newton's absolute time, Einstein might have erred? An error which costs us dear in quantum theory; an error for which there is evidence in the general relativity of black holes, and in the new notion of time advocated by Connes in his noncommutative geometry, based on the Tomita-Takesaki theory.

In quantum theory, position and momentum are raised to the status of matrices, and a commutation relation imposed on them. But the same is not done for time and energy – time is not a matrix, and there is no quantum commutation relation for time and energy. Because after all we do need time as a parameter, so that we may describe evolution. This unequal treatment of time and position prevents a truly relativistic and covariant formulation of quantum theory from being achieved. And yet, conventional `relativistic' quantum field theory in which time is not an operator continues to be the favorite formulation, because it was the first to be arrived at, and agrees extremely well with experiments. So where is the need to change it or modify it, so goes the argument. And the conceptual shortcoming – the unequal treatment of time and space – is conveniently forgotten. And yet, there does exist the Stueckelberg-Hurwitz fully relativistic quantum mechanics, in which duration time is made into an operator, there is a quantum commutator between time and energy, and a new universal time parameter is additionally introduced to describe evolution. This relativistically covariant theory reproduces all the known experimental results, while making a new prediction (quantum interference in duration time, because time is now an operator). However, the new universal time parameter is introduced almost apologetically, without the suggestion that it could be Newton's absolute time T.

Witness the case of black holes in the general theory of relativity. There is the famous black hole area theorem, according to which, in any physical processes involving black holes, their collisions and mergers, the net surface area of black holes is a non-decreasing function of time. But wait a minute. Which time is this time? It cannot be duration time, because the latter's rate of change is dynamically dependent on the gravitation of the evolving black hole geometries, and because it is mechanistic and does not prescribe a universal arrow of time. The situation could indeed have been saved if Newton's absolute time T had not been given up. The theorem would then be: the net area of black holes is a non-decreasing function of Newton's absolute time T. General relativity can well accommodate Newton's absolute time, and with benefits.

In his theory of non-commutative geometry - a successor of Riemannian geometry - Connes proves the existence of a novel time parameter, absent in the geometry of Riemann. Non-commutative geometry can be arrived at by starting from ordinary commutative geometry, mapping it to a commutative algebra of functions, then by replacing this algebra by a non-commutative algebra (e.g., the algebra of matrices) and mapping this latter algebra back to a new geometry, now non-commutative. For instance, Euclidean geometry could be mapped to the algebra of real numbers as coordinates of a manifold, replace real numbers say by matrices, or non-commuting numbers such as quaternions or octonions. And this non-commutative algebra represents a non-commutative geometry. By treating this algebra as a von Neumann algebra, the Tomita-Takesaki theorem is used to show that there exists a one-parameter family of automorphisms which serve the unique role of a time parameter. Let us call this the Tomita-Takesaki time: it is clearly distinct from duration, because duration has now been made non-commutative. The TT time does not exist for a Riemannian geometry, and it is tempting and plausible to identify it with Newton's absolute time T. TT time would serve us well in relativistic quantum field theory as well as in general relativity, and yet it has not received the attention it deserves.

There at least seven other instances of important theoretical and experimental developments in quantum theory and relativity which have taken place in the century after the discovery of the theory. One of these is Stephen Adler's theory of trace dynamics, developed in the last decade of the previous century, and described elegantly in his book `*Quantum theory as an emergent phenomenon'* (Cambridge University Press, 2004). Suppose one were to carry out Newtonian dynamics by describing particle positions, not using real numbers, but using matrices. This is the essence of trace dynamics. Quantum theory is also a matrix mechanics, but with the quantum commutator imposed by hand. In trace dynamics, no such commutator is imposed a priori; the matrices of position and momentum do not commute with each other, rather they evolve dynamically. Nonetheless, there is a beautiful theorem which says that the sum of commutators [q, p] over all degrees of freedom is conserved. Assuming trace dynamics to hold at some energy scale not yet accessed in the laboratory, one asks what the emergent dynamics at lower energy scales is. This question can be answered by applying the standard techniques of statistical thermodynamics to trace dynamics. One finds that in the emergent thermodynamic equilibrium approximation the sum of commutators is equipartitioned, and one recovers relativistic quantum field theory. Not just that, the underlying trace dynamics evolution is in general non-unitary, though deterministic. For macroscopic systems, non-unitarity becomes significant, driving the dynamical system to classicality. Trace dynamics also accounts dynamically for collapse of the wave function, and for the Born probability rule which is observed for the quantum measurements leading to classicality. Trace dynamics is thus a beautiful deterministic non-unitary dynamics which unifies the unitary

Schrödinger evolution aspect and non-unitary reduction aspect of quantum mechanics. Moreover, Adler's trace dynamics and Connes non-commutative geometry have a lot in common: both work with the non-commutative algebra of matrices, and the TT time is plausibly conjugate to the conserved sum of commutators, freeing duration time to be raised to an operator status. Yet, not many have heard of trace dynamics, even though its originator is a distinguished theoretical physicist and Professor Emeritus at the Institute of Advanced Study in Princeton.

The second instance is the discovery of Bell's inequalities in the 1960s and their subsequent confirmation by experiment. The origin of the related physics lies in the 1935 paper of Einstein, Podolosky and Rosen, where they showed that measurement on a quantum sub-system influences another correlated quantum sub-system outside the light-cone. They concluded that the quantum mechanical description of reality is incomplete (and hence additional local hidden variables are needed in the theory); else the description of space-time structure via special relativity breaks down in quantum mechanics. Bell showed that quantum systems exhibit nonlocal correlations stronger than those permitted for classical systems possessing local hidden variables. Subsequent experiments vindicated quantum nonlocality, thus ruling out classical realism once and for all. Einstein would have concluded that special relativity needs to be modified in quantum theory – that being the only way to explain how an influence (spooky action at a distance) took place outside the light-cone. And yet, the majority viewpoint is that all is well with relativity in quantum mechanics, because in any case information is not being transferred faster than light.

The third instance is directly related to the second one above, and no less significant. Popescu and Rohrlich showed that the condition of relativistic causality (i.e. no signaling) by itself permits nonlocal correlations stronger than those permitted by quantum theory. This mysterious mismatch between relativity on the one hand, and quantum mechanics on the other, raises the question as to whether there exists a dynamics more general than quantum dynamics, where such supra-quantum nonlocal correlations arise. In fact, there is evidence that such a situation arises in Adler's trace dynamics. One might ask what kind of physical systems exhibit this stronger-than-quantum nonlocality, and what experiments might find them. Yet, only rarely does this question evoke interest, and more attention is focused on saving quantum mechanics and finding additional criteria which would disallow supra-quantum nonlocality from occurring in nature.

The fourth instance concerns the tension between the quantum superposition principle and the point structure of the spacetime manifold in which quantum phenomena supposedly play out. When a massive quantum system is in a superposition of two or more position states, the gravitational field produced by it at a spacetime point is not well-defined: it is subject to the ever-present quantum fluctuations. That in turn destroys the point structure of the manifold. Imagine a low energy classical universe in which every elementary particle is in position superposition; such a universe no longer admits points in spacetime. And yet it should be possible to describe dynamics of elementary particles. Thus, it is most essential that we should find a way to reformulate quantum theory without referring to space or time. This much was obvious right from the time quantum theory was discovered. Who knows what new physics might be revealed by this reformulation! And yet, so strong is the belief in the existing version of quantum field theory that this aforesaid shortcoming receives scant attention.

The fifth instance concerns the Ghirardi-Rimini-Weber [GRW] proposal for explaining why macroscopic systems do not exhibit quantum superposition of position? Suffice it to say that the principle of quantum superposition has not been tested for in the laboratory for objects with mass greater than about 100,000 atomic mass units. From this mass to a massive object of about a microgram (which appears to behave classically), there is a grand desert of thirteen orders of magnitude where quantum theory has not been tested. This amazing fact hardly raises any eyebrows, it being almost taken for granted that quantum mechanics will continue to hold in this desert. The absence of macroscopic superpositions is attributed to the phenomenon of decoherence, and to the Everettian interpretation of quantum mechanics. Where the wave function is said to not collapse at all, and yet (unsuccessful) attempts have been made to derive the Born probability rule in the Everett picture. But if there is no collapse and the evolution is deterministic, why should there be probabilities? In contrast to Everett, GRW propose that collapse is a dynamical process – extremely rare for microscopic systems, and very frequent for macroscopic systems. This idea is falsifiable, unlike Everett, and enough to explain why large objects do not exhibit superpositions. Trace dynamics provides a theoretical underpinning for the GRW phenomenology. GRW can also be turned into a relativistic theory, by raising time to an operator, bringing in TT time, and allowing for dynamical spontaneous collapse of duration time. Even so, the establishment viewpoint is strongly tilted in favor of Everett, and GRW theory and its experimental tests constitute fringe physics at present. Once again, status quo is preferred, simply because no experiment contradicts the status quo.

The sixth instance concerns Pascual Jordan's algebraic formulation of quantum mechanics, given soon after the Heisenberg and Schrödinger version of the theory. Jordan's point was that Hermitian matrices do not form a closed algebra under matrix multiplication, whereas they do under the Jordan product, this latter being defined as one half the commutator of product of two matrices. It was then shown that Jordan's version of quantum theory is equivalent to conventional quantum theory, except in one case, when the matrices in question are 3x3 Hermitian matrices with octonions as elements. A few researchers have suggested that this so-called exceptional Jordan algebra might contain new physics beyond quantum theory and general relativity. A handful of researchers are also looking into the possible role octonions might play in our understanding of the standard model of particle physics. However, this enterprise also largely remains fringe physics, because at first sight it seems removed from mainstream quantum field theory.

The seventh instance has to do with the general theory of relativity in the astrophysical domain, and with the flat rotation curves found in hundreds of galaxies. In every such galaxy it is observed that when the measured value of the gravitational acceleration of a star (orbiting the galaxy) falls below a universal critical value a_0 (this being about 10^{-8} cm/sec^2), the rotation curve of the galaxy no longer obeys Newton's inverse-square law of gravitation. This in turn implies that general relativity is breaking down whenever the orbital acceleration falls below a_0. This is a clear-cut signature that the law of gravitation is something other than Newton's / Einstein's for accelerations below a_0. There is a phenomenological modification of the law, at accelerations below a_0, due to the physicist Mordehai Milgrom, and known as Modified Newtonian Dynamics (MOND). MOND also explains why this critical acceleration happens to be the same order of magnitude as the currently observed acceleration of the universe. MOND invariably correctly predicts the rotation curve of a galaxy once the luminous matter distribution is given. And yet, MOND is not considered the most likely explanation for flat galaxy rotation curves; it is fringe physics. The most popular explanation is that there is additional invisible dark matter, which contributes to changing the value of the orbital acceleration, while Newtonian gravitation continues to be valid. This even though the dark matter hypothesis does not have a convincing natural explanation for the scale a_0, nor can it predict the rotation curve of a galaxy from the distribution of stars and gas. First the rotation curve must be given as input data, and then the dark matter distribution must be worked out, case by case, galaxy by galaxy, to derive the observed rotation curve. To any objective researcher MOND would be seen as a clear winner. And yet, it is dark matter all the way, even though the standard model of particle physics provides no convincing dark matter particle candidate. Scores of sincere experimental searches for dark matter particles have come back empty handed. It is tempting to ponder what if Johannes Kepler and Vera Rubin were contemporaries and had jointly presented their data to Newton, what would he have come up with? Would he propose the inverse square law of gravitation in the solar system, but dark matter on galactic scales? Or a unified law of gravitation which accounts for planetary motion as well as for orbits of stars around the galactic center?

Why then is the dark matter hypothesis so much more popular than MOND? For two reasons, one of which is reasonable, the other unreasonable! The reasonable reason is that MOND is a phenomenological proposal; a convincing fundamental underlying theory for MOND is lacking as of now. Such a theory should naturally reduce to general relativity for accelerations much larger than a_0 and to MOND for accelerations much smaller than a_0. The unreasonable reason is that the cold dark matter hypothesis is spectacularly successful on cosmic scales when it comes to explaining the observed temperature anisotropies of the cosmic microwave background. Whereas MOND does not at all do well on this count. But is this a good enough reason for batting for dark matter on galactic scales as well, and throwing out MOND on galactic scales as well? The rational scientific stance should be: dark matter does much better than MOND on cosmic scales, and MOND does much better than dark matter on galactic scales. But the proponents of the dark matter hypothesis want MOND thrown out of the window once and for all, on all scales.

We have highlighted two breakthrough experiments / observations, one the experimental confirmation of quantum nonlocality, and other the discovery of flat galaxy rotation curves. Between them they are enough to shake up quantum theory as well as relativity, but that has not happened. Dark matter has been invoked to save general relativity, and the repercussions of quantum nonlocality are simply ignored as being insignificant. A breakthrough experiment is not a breakthrough experiment until the majority accept it as such! Same goes for theoretical breakthroughs such as trace dynamics, GRW collapse theory, Tomita-Takesaki time, Popescu-Rohrlich nonlocal correlations, the exceptional Jordan algebra, and MOND. These advances should have stirred up quantum field theory and general relativity, but that has not happened. Very few researchers are working on these developments, not many science enthusiasts have heard of them. This even though the standard model of particle physics, whose bedrock is quantum field theory and special relativity, has twenty-six free parameters whose values are only known through experiment, and which go by the name of fundamental constants. von Neumann used to say give me four free parameters and I can fit an elephant, give me five and I will make the elephant wag its tail. The standard model has twenty-six! And yet it is presented as a great success because it `explains' all particle physics experiments to date. The seven instances we have cited above could have implications for the standard model and could fix some of its free parameters, but such a proposal does not find much favor amongst researchers.

Contrast this with the string theory revolution which has now lasted half a century, and which is still believed by many to be the eventual theory of everything. This even though string theory has thus far not yielded a theory of unification of forces, nor is it able to derive even one out of the twenty-six fundamental constants of the standard model. Consequently, many have come to believe that these constants can only be measured but cannot be derived. And that they take different values in different multiverses – even though there is no observational evidence for such verses, nor a theorem in physics which says these constants are not unique and cannot be derived from first principles. Undoubtedly, string theory is beautiful and has made lasting and extraordinary contributions to mathematics and to mathematical physics, and it will likely be part of the ultimate theory of unification. But in its present form string theory does not explain the world we see (why is the muon 200 times heavier than the electron), and sadly it does not consider the foundational advances we have listed above. String theory would likely benefit if it paid heed to these theoretical advances, instead of merely being the relativistic quantum field theory of extended objects.

Despite its grand failure at unification, why is string theory so popular still?! This has less to do with science, and more to do with personalities, grants, funding, jobs, prestige. Half a century is short enough a span that the discoverers of string theory, extremely capable and distinguished scientists, hold sway over prevailing physics ideology. It is human nature that they cling to the fond hope that their beautiful baby harbors truth and will yield fruit someday. What is less easy to understand is their stubborn stance that quantum theory and relativity need no redoing before string theory delivers unification. Perhaps it is the ghost of Bohr, a relic of the Bohr-Einstein dialogues, which hangs on strong still: do not ask foundational questions of quantum mechanics, they are a waste of time, just shut up and calculate.

In holding on to pragmatism and shying away from philosophical questions in fundamental physics, we have let the pendulum swing too far the other way. Quantum mechanics could have been different. Relativity could have been different. The instances we have pointed out could have been paid greater attention to, deservedly so. Theoretical breakthroughs could have been absorbed into the conventional formalism of quantum field theory. There could have been international conferences with titles such as `The significance of quantum foundations for the standard model of particle physics'. Or, say `String theory and the quantum measurement problem'. Or, say, `MOND confronts dark matter'. Sadly, such conferences never take place. We are comfortable in our miniature diasporas: the string diaspora, the GRW theory diaspora, the MOND diaspora, the trace dynamics diaspora, the octonions diaspora, … We do not like making bridges; they lead to academic confrontations, they are disruptive, they are threats to entrenched positions.

The saving grace is that Nature is supreme, and over the time scale of a few centuries truth asserts itself unquestionably and we human beings fall in line, eventually, though grudgingly. The breakthrough experiment can be ignored no longer, and a new theoretical framework overruns the older one, often put together from the instances we have described. As of today, Newton's mechanics, Maxwell's electrodynamics, and to a large degree special relativity, all are robust frameworks in their respective domains of validity. On the other hand, quantum theory, and general relativity as a theory of gravitation, are still in their infancy, and our understanding of these theories is evolving. They could have shaped up differently since their discovery a century ago. Nonetheless eventually they will take their final true and convincing form, because as a human collective we are adherents of scientific truth. As individuals we are dogmatic and fallible, but as a civilization we are honest lovers of that which is true. Mankind overall is made not of rogues but of good human beings. And that is why our scientific enterprise begun a few centuries ago continues to follow the established scientific method, topsy-turvy enroute, but steady and fruitful in the long run.

What could we try to speed up scientific discovery, and make it less confrontational? Science research is a collective human enterprise; it is not a competition about who did it first. We need to teach our children the art of deep listening, so that they may grow up into adults who absorb deeply what the other person is saying and imbibe it in their own thought process. That something is sorely missing in human communication can be felt in these remarks by Ella Deloria:

"We Indians know about silence. We are not afraid of it. In fact, for us, silence is more powerful than words. Our elders were trained in the ways of silence, and they handed over this knowledge to us. Observe, listen, and then act, they would tell us. That was the manner of living.

With you, it is just the opposite. You learn by talking. You reward the children that talk the most at school. In your parties, you all try to talk at the same time. In your work, you are always having meetings in which everybody interrupts everybody and all talk five, ten or a hundred times. And you call that 'solving a problem'. When you are in a room and there is silence, you get nervous. You must fill the space with sounds. So you talk compulsorily, even before you know what you are going to say.

White people love to discuss. They don't even allow the other person to finish a sentence. They always interrupt. For us Indians, this looks like bad manners or even stupidity. If you start talking, I'm not going to interrupt you. I will listen. Maybe I'll stop listening if I don't like what you are saying, but I won't interrupt you.

When you finish speaking, I'll make up my mind about what you said, but I will not tell you I don't agree unless it is important. Otherwise, I'll just keep quiet and I'll go away. You have told me all I need to know. There is no more to be said. But this is not enough for the majority of white people.

People should regard their words as seeds. They should sow them, and then allow them to grow in silence. Our elders taught us that the earth is always talking to us, but we should keep silent in order to hear her.

There are many voices besides ours. Many voices…"

And the world of science research needs to eliminate academic bullying, so that free thought could prevail without fear. Academic bullying is a serious disease that hampers progress, as noted by Tauber and Mahmoudi (How bullying becomes a career tool, Nature Human Behaviour 6, 475

(2022)). No less a luminary than the great astrophysicist Subrahmanyan Chandrasekhar was affected. He writes:

"I think one of the motives of science is to leave some kind of memorial behind oneself. And people can do that in a variety of ways. They can make discoveries and be remembered for that. But there is also a more modest role a scientist can play, and that is to assemble information and material which, in the long run, will be helpful to others, and be of some permanent value permanent in a relative sense. I have chosen the later approach. All, I think, as a consequence of my first shattering experience in Cambridge [this refers to the famous drubbing that Chandrasekhar got at the hands of Eddington regarding what later came to be called the Chandrasekhar limit - Eddington was squarely wrong in this case].

The idea that one's scientific life has to be motivated by the off-chance that one may make a great discovery, and be remembered for that, was too risky, too much of a gamble. I preferred the more modest approach of trying to do something and I think, on the whole, it has worked to my advantage. Because if one is not stupid, then in the course of such effort you are bound to find a few things which people might even count as important discoveries. But the main emphasis in your life is to concentrate on producing as permanent a body of knowledge as you are capable of."

May no one in science have such a shattering experience. May discovery not be tainted by gender, race, sexual orientation, political beliefs, or geographic location of the discoverer. May the cold logic of the discovery speak for itself. In this vital regard, the art of practicing science could have been different. Our planet is not a safe haven in the universe. And we are not making things any better – our greed is undoing us. The scientific method is in very good shape, but how we scientists treat each other could have been different. This can help save us from self-destruction, and from being wiped out by some unforeseen agency from outer space.