When words fail

Scientists have to struggle with words that don't fit reality.

Frank Wilczek

Language is a social creation. It encodes the common experience of many people, past and present, and has been sculpted mainly to communicate our everyday needs. Ordinary language is most certainly not a product of the critical investigation of concepts. Yet scientists learn, think and communicate in it during much of their lives. Ordinary language is therefore an unavoidable scientific tool — rich and powerful, but also quite imperfect.

One scientific imperfection of language, perhaps the most obvious, is its incompleteness. For example, there are no common words for several of the most central concepts of quantum theory, such as the linearity of state-space and the use of tensor products to describe composite systems. To be sure, we've developed some applicable jargon — 'superposition' and 'entanglement', respectively, are the words we use — but the words are unusual ones, not likely to convey much to outsiders, and their literal meaning is misleading to boot.

Although it creates cultural barriers and contributes to the balkanization of knowledge, such enrichment and slight abuse of language is not conceptually problematic. Much more insidious, and more fundamentally interesting, is the opposite case: when ordinary language is *too* complete. When something has a name, and is commonly employed in discourse, it is seductive to assume that it refers to a coherent concept, and an element of reality. But it need not. And the more pervasive the word, the more difficult it can be to evade its spell.

Few words are more pervasive than 'now'. According to his own account, the greatest difficulty Einstein encountered in reaching the special theory of relativity was the necessity to break free from the idea that there is an objective, universal 'now': "[A]ll attempts to clarify this paradox satisfactorily were condemned to failure as long as the axiom of the absolute character of times, *viz.*, of simultaneity, unrecognizedly was anchored in the unconscious. Clearly to recognize this axiom and its arbitrary character really implies already the solution of the problem."[1]

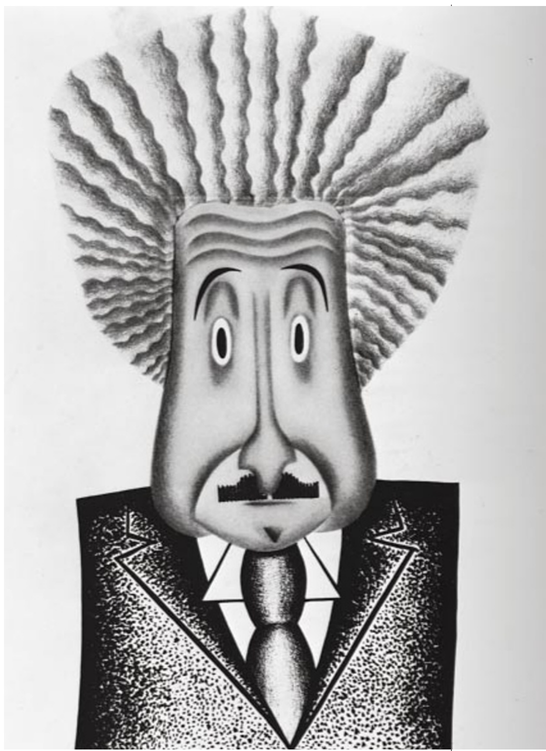
Einstein's original 1905 paper begins with a lengthy discussion, practically free of equations, of the physical operations involved in synchronizing clocks at distant points. He then shows that these same operations, implemented by a moving system of observers, leads to differing determinations of which events occur "at the same time".

As relativity undermines 'now', quantum theory undermines 'here'. Heisenberg had Einstein's analysis specifically in mind when, in the opening of his seminal paper on the new quantum mechanics in 1925, he advocated the formulation of physical laws using observable quantities only. But while classical theory has a naïve conception of a particle's position, described by a single coordinate (a triple of numbers, for three-dimensional space), quantum theory requires this to be replaced by a much more abstract quantity. One aspect of the situation is that if you don't measure the position, you must not assume that it has a definite value. Many successful calculations of physical processes using quantum mechanics are based on performing a precise form of averaging over many different positions where a particle 'might be found'. These calculations would be ruined if you assumed that the particle was always at some definite place. You can choose to measure its position, but performing such a measurement involves disturbing the particle. It changes both the question and the answer.

Einstein himself was never reconciled to the loss of 'here'. In his greatest achievement, the general theory of relativity, Einstein relied heavily on the primitive notions of events in space–time and (proper) distance between nearby events. These notions rely on unambiguous association of times and places — 'nows' and 'heres' — to individual objects of reality (though not, of course, on the existence of a universal 'now'). Understandably impressed by the success of his theory, Einstein was loath to sacrifice its premises. He resisted modern quantum theory, and did not participate in its sweeping success in elucidating problem after great problem.

Ironically, the sacrifice he feared has not (yet) proved necessary. On the contrary, in the modern Theory of Matter, we retain 'nows' and 'heres' for the fundamental objects of reality. These primitives are no less important in the formulation of the subatomic laws of quantum theory than in general relativity. The new feature is that the fundamental objects of reality are one step removed from the directly observed: they are quantum fields, rather than physical events.

It is possible to avoid ordinary language and its snares. Within specific domains of mathematics, this is accomplished by constructing exact definitions and axioms. Purity of language is also forced on us when we interact with modern digital computers, since they do not tolerate ambiguity.



Time trial: Einstein found it hard to break free of the idea of 'now'.

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But the purity of artificial languages comes at a great cost in scope, suppleness and flexibility. Perhaps computers will become truly intelligent when they learn to be tolerant of ordinary, sloppy language — and then to use it themselves! In any case, for us humans the practical and wise course will be to continue to use ordinary language, even for abstract scientific investigations, but to be very suspicious of it. Along these lines, Heisenberg's considered formulation, put forward in *The Physical Principles of Quantum Theory* in 1930, was: "[I]t is found advisable to introduce a great wealth of concepts into a physical theory, without attempting to justify them rigorously, and then to allow experiment to decide at what points a revision is necessary."

Looking to the future, after 'now' and 'here', what basic intuition will next require reformation? As the nature of mind comes into scientific focus, might it be 'I'? Perhaps the following remarks of Hermann Weyl, stimulated by deep reflection on the aspects of modern physics discussed here and stated in his *Philosophy of Mathematics and Natural Science* (1949), point in that direction: "The objective world simply is, *it does not happen*. Only to the gaze of my consciousness, crawling upward along the life line of my body, does a section of this world come to life as a fleeting image in space which continuously changes in time." ■

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1. Einstein, A. "Autobiographical notes" in *Albert Einstein, Philosopher-Scientist* (ed. Schilpp, P.) (Library of Living Philosophers, 1949).