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Quantum Poetics

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Popular science writing is an act of translation. This is true especially in writing about physics, whose mathematical language is far from everyday speech. But the industry of physics writing might promise more than it can deliver, particularly when it tries to offer descriptions of fundamental physical reality that, so we are sometimes told, dispel the illusions we get from ordinary experience. As with translating literary works from their original language into another, we need to ask the question of translatability—of whether and how a concept or theory in physics can be rendered in ordinary language. Straightforward description may be more elusive than we assume.

In the twentieth century, some physicists, notably Robert Oppenheimer, worried that physics had reached a point of extreme alienation from popular language, and even from the language of other scientific disciplines. Intelligibility to non-physicists was becoming increasingly difficult, in some cases even impossible.

Many physicists and science writers today seem more optimistic. While recognizing the distance between physics and ordinary language, they tend to believe that our language can be transformed to make the truths of physics available to a wide public audience. For instance, physicist Frank Wilczek writes that "Modern physics has opened up imaginative possibilities for cosmology that outrun the anticipations of ordinary language. To do them justice, we must both refine and expand everyday usage."

The question of whether and how physics can be rendered in ordinary speech is nowhere more important than in our assessment of writers who try to present a vision of the world that is wholly other than what our everyday experience would have us believe, a world that, many think, is more real. This is the spirit of the recent book *Reality Is Not What It Seems* by theoretical physicist Carlo Rovelli, which promises to be a "magic journey out of our commonsense view of things, far from complete."

There is something deeply paradoxical about this project. On the one hand, it is motivated by a desire to dispel everyday illusions about the physical world that contribute to our human-centeredness. "We are obsessed with ourselves," writes Rovelli. "We study *our* history, *our* psychology, *our*

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philosophy, *our* gods. Much of our knowledge revolves around ourselves, as if we were the most important thing in the universe." Physics, he thinks, can teach us better.

On the other hand, the only way to take a popular audience on this "journey out of our commonsense view of things" in writing is in commonsense language, which is intricately tied to our everyday experience of the world. Writers therefore try to make physics intelligible to the general reader by translating esoteric mathematical theories into plain terms, while at the same time trying to show how conventional descriptions of the world as it appears to us do not match up with physicists' descriptions of actual reality. This is a vexing task. The liberal use of scare quotes around familiar words in Rovelli's writing—a single page in his bestselling *Seven Brief Lessons on Physics* has "time," "position," "flow," "present," "now," and "here" all between quote marks—is a sign of strain, of trying to press uncommon meanings into common words.

There is another, related sign of this strain, one that helps us to think more broadly about the modern project of offering a strictly scientific description of the world. Marcelo Gleiser has written that Rovelli is one of the few "physicist-poets," who see the physical world as "a lyrical narrative." But although it is true that Rovelli's writing is rich in poetic expressions, poetry broadly conceived has been a prominent feature of popular physics writing for the last century or so. In addition to offering what we usually think of as *descriptions* of the world in straightforward explanatory terms, writers often present *poetic images* to gesture at the strange new mathematical world of physics. Metaphors and analogies are critical: "Imagine that you work in a Kafkaesque office complex, an infinite chain of cubicle after cubicle" (Gleiser, describing baryon numbers); "Once geometry…is encoded as a mathematical fluid, we can easily envisage that the fluid flows and takes on a life of its own" (Wilczek); "space is a fluctuating swarm of quanta of gravity" (Rovelli).

It is a modern conceit that we have advanced from the poetic imaginations of the ancients to clear scientific description, leaving behind the quaint and parochial ways of speaking about the physical world. Poetic imagery, after all, is the kind of language that is the most parochial, most personal, and most dependent on our everyday experience. Its use in writing about physics is not simply a mark of ancient ignorance, nor mere embellishment in popular writing, nor just a sign of the bemused writer's amazement at the world as physicists know it; rather, those aspects of physics that touch on the fundamental nature of the universe can't always get squeezed into descriptive terms. This means that the widely shared ideal of describing ultimate reality purely in terms of physics is futile, at least if we mean verbal, not mathematical, description. And if poetry is necessary for talking about the foundations of physical reality, this should both elevate the importance of poetry and help to disabuse us of the idea that we can exclude the more personal, parochial, poetic forms of language and still truly apprehend reality.

Scientific Description vs. Poetic Image

The rift between scientific language—consisting of clearly defined descriptive terms—and non-scientific language—which is more ambiguous, haphazard, and often metaphorical—goes back to the very beginning of the modern scientific project. One class of Francis Bacon's famous "idols" of the mind—the false images of reality that he believed philosophers were fixated on to the detriment of good science—is the "idols of the marketplace." These idols are words from everyday chatter, both popular and scholarly, that sit comfortably in our vocabularies but lack unambiguous counterparts among the things in the real world, making clear reasoning impossible.

There are two kinds of word idols, Bacon explains. First, there are "names of things which do not exist…or they are names of things which exist, but yet confused and ill-defined, and hastily and irregularly derived from realities." Among them are: "Fortune, the Prime Mover, Planetary Orbits, Element of Fire, and like fictions which owe their origin to false and idle theories." Second, there are words that have multiple meanings. A word of this kind—his example is "humid"—is "nothing else than a mark loosely and confusedly applied to denote a variety of actions which will not bear to be reduced to any constant meaning."

In Bacon's new science, words of both kinds are to be shunned, and so part of science is the need continuously to cleanse language of its imprecise and misleading words or meanings, and to find more fitting ones, because purification of language, and thus of thinking, is necessary for apprehending the world truly. But this way of putting it makes clear the value judgment against non-scientific, popular, or more poetic ways of speaking. They can soil scientific discourse, and as the gap between scientific and non-scientific language—and the according need for translation—grows, so grows the importance for translators to stay clear of imprecise words or to offer precise definitions when needed.

Underlying Bacon's call for a scientifically strict language, and his judgment against words of the "marketplace," seems to be a larger point about how language changes over time as our scientific knowledge increases. In his 1609 work *Wisdom of the Ancients*—a retelling of classic fables with fresh interpretations—Bacon explains that parables and metaphors are useful for teaching people difficult concepts, which is why, in the ancient days of greater ignorance, so many fables were written. As popular ("vulgar") knowledge grows, metaphors give way to scientific arguments. Even so, the poets and storytellers remain useful for introducing arcane scientific insights, which then over time can again be rendered in the language of science. The method of teaching by parables is, Bacon writes,

> exceedingly useful, and sometimes necessary in the sciences, as it opens an easy and familiar passage to the human understanding, in all new discoveries that are abstruse and out of the road of vulgar opinions. Hence, in the first ages, when such inventions and conclusions of the human reason as are now trite and common were new and little known, all things abounded with fables, parables, similes, comparisons, and allusions, which were not intended to conceal, but to inform and teach.... For as hieroglyphics were in use before writing, so were parables in use before arguments. And even to this day, if any man would let new light in upon the human understanding,... he must still go in the same path, and have recourse to the like method of allegory, metaphor, and allusion.

Descriptive terms ultimately win out over poetic images, which are merely a temporary tool for instruction, and of which a mature mind, accustomed to scientific discourse, will have little need. Similar ideas about the historical progression of scientific language from *poetic* to *descriptive* have been proposed by others in the modern era, for instance by the historian Giambattista Vico in the 1700s and the philosopher Auguste Comte in the 1800s. Often these ideas are about the development not just of scientific language but of human understanding of nature per se: By Bacon's way of thinking, the progression from poetry to science is both a large historical development and also a proper development for any scientifically minded person, because descriptive terms are superior tools for understanding. Unlike poetic images, they are linked directly to things in the world or to concepts neatly abstracted from those things, like Adam naming the animals, to use an analogy for natural science in Bacon's preface to *The Great Instauration.*

Bacon was of course right that scientific apprehension of reality is impossible without an orderly vocabulary. But there are at least two important limitations to the idea that scientific description replaces poetic images over time, once they have served their purpose of instructing the uninitiated. One limitation is the boundary of science itself, the other is internal to science; both will help us see why scientific description is not enough.

First, consider the areas of life and study for which scientific description contributes little to our understanding. Precisely defined terms are often superior to poetic images for the purposes of science, but the opposite is true in our own personal experience of the world—the poetic image, while more vague, is also more meaningful and a better fit for understanding our own inner lives as well as the messy affairs of politics, history, and ethics. One reason we don't typically use the language of science in those areas is that science's "view from nowhere" calls for more impersonal language than does our own view.

The second limitation to the triumph of scientific description arises in physics itself, which in some respects seems to be an exception to the descriptive ideal. As the language of physics has become increasingly mathematical, that is, increasingly wordless, translating physics into words appears to have made necessary the use of poetic, imaginative expressions. This is the case whether physics is being translated into commonsense *or* scientific words, and is particularly the case when talking about the fundamental nature of matter and the universe.

Far from making poetic speech a mere means of translating a scientific message, talking about the constitution of the physical world must be poetic in some way. It is for this reason that Rovelli's reliance on poetic images is a matter not just of style but of the way description alone may, in the far reaches of physics, no longer be the best mode of speaking about the world.

Bacon in Vienna

One way to clarify the different domains of *scientific description* and *poetic image* is by looking at a few texts from early-twentieth-century Vienna, where the distinction between these forms of language was a preoccupation of the city's thinkers. One of them was the writer Hugo von Hofmannsthal, who in the early 1890s, when he was still a teenager, gained a reputation as perhaps the greatest poetic master since Goethe. The writer Stefan Zweig later said that Hofmannsthal "in his sixteenth and seventeenth years had inscribed himself upon the eternal rolls of the German language."

Hofmannsthal had a stellar career in the world of arts and letters ahead of him. But sometime around the age of twenty-six he began to suffer a creative crisis that lasted for roughly two years, at the end of which, in 1902, he published a letter, addressed to Francis Bacon and taking up Bacon's ideas about language. Although Hofmannsthal is not widely known outside the German-speaking world today, his letter to Bacon would become one of the foundational texts of modernist literature in the early twentieth century.

The fictional author of the letter is Philipp Lord Chandos, "the younger son of the Earl of Bath," as a prefatory comment explains, and a protégé of Bacon. Chandos begins his letter with an elaborate apology for his two-year silence since his last publication, going on at some length about the extensive writing projects he has been unable to put to paper. What appeared to him once as "one great unity" of matter and mind, and of himself and the world, has split into fragments to the point that thinking and speaking about anything seems to have become impossible. The reason for his creative crisis and for his silence, he explains, is his literal loss for words to bring coherence to the fragments of experience. "In brief, this is my case: I have completely lost the ability to think or speak coherently about anything at all."

But the letter's exquisite prose belies Chandos's claim. The question of what to make of the irony of eloquently giving expression to one's inability to write—and of how to interpret the letter as a whole—has been the subject of scholarly logorrhea ever since. The most illuminating readings, at least for our purposes, are those that take a close look at the letter's addressee, Bacon. (Though we will not address them directly here, H. Stefan Schultz and Timo Günther are among the authors who have offered such readings.)

While never saying so explicitly, Hofmannsthal seems to suggest that Bacon is wrong to elevate scientific descriptions above poetic images as ways of understanding the world. This elevation is wrong, at least, for non-scientific domains such as politics, ethics, faith, and everyday life—the subjects Chandos's failed writing projects would have been about.

One of these projects was to unlock the fables and mythical tales of the ancients, which are like "hieroglyphics of a secret, inexhaustible wisdom." This is the very project Bacon himself did in fact undertake. Bacon tried to extract a single meaning from the complexity of each fable, believing that the *actual*, if veiled, content of the poetic image can be made explicit in descriptive terms—for instance, the myth of Proteus, the herdsman of the sea, is about "the secrets of nature," how different forms of matter under torture can be transformed. But Chandos's letter pushes in the other direction, offering poetically rich images whose full meaning would be lost if one tried to put their content into plain terms. For example, describing his creative schemes, he writes that "they dance before me like miserable mosquitoes on a dim wall no longer illuminated by the bright sun of a happy time, each of them engorged with a drop of my blood."

Poetic images, rather than scientific terms, may in fact be best suited for expressing ideas about such personal and psychologically complex matters. Part of the reason for this, surely, is that for Bacon's project of purifying language, scientific description requires strict definitions that tie words to things *in the world.* When that project is taken to its logical conclusion, anything that isn't directly available to sensory perception from an objective perspective, or to the scientific instruments extending that perspective—our thoughts, moral judgments, religious experience, and so forth—would therefore seem to escape verbal expression. Committed to his master's ideas about precision of descriptive terms, Chandos feels he must be silent about the things he had hoped to speak about, because they would require going beyond discussing mere sensory perception. Abstract words, he says, "which the tongue must enlist as a matter of course in order to bring out an opinion disintegrated in my mouth like rotten mushrooms." Fixated on the unique particularity of all things, on parts, and parts of parts, finding any words to unify them into wholes seems unachievable. No book will ever be possible for him to write:

> It is that the language in which I might have been granted the opportunity not only to write but also to think is not Latin or English, or Italian, or Spanish, but a language of which I know not one word, a language in which mute things speak to me and in which I will perhaps have something to say for myself someday when I am dead and standing before an unknown judge.

In short, one way to describe Chandos's crisis is that the modern, scientific mode of language—striving to achieve comprehensive understanding through descriptive terms alone—demands an ideal that is in principle impossible to achieve, especially in non-scientific areas of thought. Part of this ideal of description is that each word needs to be a perfect label for the thing to which it refers. But making sure of this would require a never-ending investigation into things, demanding a definition for each word before using it. And if we were to insist on defining all our terms before using them, then our definitions, consisting of words, would in turn require definitions—a mentally paralyzing pursuit. The only "language" Chandos can conceive of using to break the chain is one that mute things speak—the immediate, wordless impression that any object can make on a receptive soul: a watering can in the garden, a dog lying in the sun, an old church yard.

To be fair to Bacon, he surely did not mean that we should be silent until we have defined all our words and nailed them down to physical realities. Nevertheless, we can think about what his project of making language useful for scientific understanding means for talking about things other than science, the areas that Chandos had planned to write about. If we tried to imagine (if we can) a language that avoids all ambiguities, multiplicity of meanings, and ill-defined words, and that insisted on near-perfect links between words and things in the world, this language would seem to be useful for talking only about the empirically most discrete realities. We might use it for talking about physics but not politics, electrons but not ethics, matter but not mind; a descriptive language that faithfully avoids the idols of the marketplace includes "brain" but not "soul," "useful" but not "virtuous," "oxytocin" but not "love."

This point highlights an important caveat. While the issue here is central to the philosophy of language—the study of how words have meaning and how language relates to reality—the underlying concern in the Chandos letter is less abstract and philosophical. It is the desire, motivated by deep moral seriousness, to find a form of expression that does justice to ideas about ethics, politics, and personal experience, and to think about the limits that a scientific language, tailored to the needs of science, puts on that expression.

To illustrate this desire, as well as its frustrations, we can look at another example from Viennese literature, Robert Musil's massive but unfinished novel *The Man Without Qualities*, published in three volumes between 1930 and 1943. It opens with a memorable passage about the difference between scientific and mundane forms of expression:

> A barometric low hung over the Atlantic. It moved eastward toward a high-pressure area over Russia without as yet showing any inclination to bypass this high in a northerly direction. The isotherms and isotheres were functioning as they should. The air temperature was appropriate relative to the annual mean temperature and to the aperiodic monthly fluctuations of the temperature.... In a word that characterizes the facts fairly accurately, even if it is a bit old-fashioned: It was a fine day in August 1913.

The deeper issue unfolding over the course of the novel is the difficulty, as with Chandos, of speaking about the most deeply personal matters of life. One character explains that "the real truth between two people cannot be put into words." Or, in one of Musil's rich poetic images: "Words leap like monkeys from tree to tree, but in that dark place where a man has his roots he is deprived of their kind mediation."

The titular character of Musil's novel is much like Chandos: The mathematician Ulrich despairs of speaking coherently about politics, ethics, and love, and is unable to bring to completion his own writing project. On the one hand, Ulrich, like Bacon, seems committed to the Edenic work of naming things. He takes comfort in "the primordial magic by which possession of the correct name bestows protection from the untamed wildness of things"—for example, when we know the correct name of a flower and so sense a measure of control over it. On the other hand, Ulrich says, "certainly, human terms are created in order to correspond to the world, since that is their purpose; and so in the end it still remains an oddly open question why they never bring this to pass precisely in the sphere of the just and the beautiful."* Throughout the novel, there are frequent moments of silence in conversations about politics, morality, beauty, and the nature of love.

Another Viennese of the same time, the philosopher Ludwig Wittgenstein, reached a similar conclusion about the limits of systematically rigorous language in his landmark 1921 treatise *Tractatus Logico-Philosophicus.* After mapping out what a language would look like whose logic is a perfect match for the logic of the world—a language in which the problem of defining the precise meaning of words and sentences were solved—he concludes that subjects like the meaning of life, ethics, and faith would have to be outside its scope. "We feel that even when all *possible* scientific questions have been answered, the problems of life remain completely untouched." And because in this language restricted to facts the problems of life are unanswerable, "what we cannot speak about we must pass over in silence."

While Wittgenstein's philosophical heirs—the logical positivists of the Vienna Circle and some strands of Anglo-American analytic philosophy—generally took this to mean that the subjects beyond this perfected language can be safely ignored, Wittgenstein himself believed

* This line from the posthumously published galley chapters revised by Musil has not been included in the English edition of *The Man Without Qualities* by Sophie Wilkins and Burton Pike, to the best of my knowledge. I have translated the text borrowing language from their version of the unrevised galleys, in which Ulrich makes a slightly different point, not about language.

that it is precisely those subjects that are the most important. Writing in a letter about his thesis, he explained, "My work consists of two parts: the one presented here plus all that I have *not* written. And *it is precisely this second part that is the important one.*" And, like Chandos, Wittgenstein suggested that there needs to be a different way than this restricted language for addressing that second part.

In their book about Wittgenstein and his Viennese context, Allan Janik and Stephen Toulmin write that the goal of the *Tractatus* was "solving the problem of the nature and limits of description" and that the book's ultimate thrust was "the ethical point that all questions about value lie *outside* the scope of such ordinary factual or descriptive language." By this way of thinking, they argue, "poetry is the sphere in which the *sense* of life is expressed, a sphere which therefore cannot be described in *factual* terms." But better yet than in any philosophical book on Wittgenstein, the problems with remaining within the bounds of an empirical, facts-only language are perhaps best illustrated in David Markson's 1988 novel *Wittgenstein's Mistress*, and David Foster Wallace's afterword (originally a review of the book). The novel, as Wallace writes, asks the question, "What if somebody really had to *live* in a *Tractatus*ized world?" The answer is perfect loneliness, because no number of clear-cut facts can add up to experiencing the social, moral dimension of human life.

The later Wittgenstein rigorously dismantled the understanding of language he had put forth in the *Tractatus*, showing instead that language as we actually speak it inevitably involves ambiguities and tensions between various uses of the same words, that no perfect match between the logic of a language and the logic of the world exists, and that the meaning of words depends not on definitions nor the meaning of sentences on some fixed logical structure; rather, meaning depends on the shared contexts in which we speak in order to achieve certain purposes. While this is by far the more persuasive view of how language works, we might still say that the language of science can be seen as an attempt, however approximate, to achieve something akin to the early Wittgenstein's idea of a logically rigorous language that depicts the world in a one-to-one correspondence—a language whose scope, therefore, is strictly limited to what's describable, somewhat like Bacon imagined. Not that there aren't important differences between this idea and Bacon's ideal of exact definitions. But as Charles Taylor argues in *The Language Animal* (2016), despite the dramatic shifts in language philosophy in the late nineteenth and early twentieth centuries, one of the features that has been largely retained since the early moderns is treating a "regimented language of accurate description and inference as the key to language in general." And so the type of language that's most useful in science is still often taken as a model for how to say anything true about the world.

We should not dismiss that modern science owes at least some of its success to Bacon's advice to rely as much as possible on clear descriptions and careful definitions, instead of ambiguous poetic images, for expressing what the physical world is like. But a language sufficiently refined for describing the physical realities science seeks to explain is ill suited for expressing human experience. Although this should be a banal observation, it bucks what we are often told today: that science has the final word in all areas of investigation, and all explanations are in theory reducible to descriptions of the physical world. But the language of physics itself, as we will see, is often beyond translation into ordinary language, except in a very rough and poetic sense. And so physics, while sometimes presented as the ideal of scientific description that would overrule the ordinary, parochial, personal accounts of experience, depends for its verbal self-expression on the kind of language—poetic imagery—that we tend to think of as ancient and inferior.

Poetry's Return

Physics has discovered that the deep structures of the material world are written, as it were, in the language of mathematics, or, at any rate, that mathematics is best suited for describing those structures. Galileo famously wrote that the book of Nature "is written in the language of mathematics." Einstein expressed the same idea when he said in a 1933 lecture:

> Our experience up to date justifies us in feeling sure that in Nature is actualized the ideal of mathematical simplicity. It is my conviction that pure mathematical construction enables us to discover the concepts and the laws connecting them which give us the key to the understanding of the phenomena of Nature.

Similarly, Niels Bohr wrote in *Atomic Theory and the Description of Nature* that "The hope...that mathematical analysis would...prove capable of assisting the physicist to surmount his difficulties has...been fulfilled beyond all expectations."

As physicists over the past three or four centuries have relied increasingly on mathematics rather than the word to describe the world, physics, like mathematics itself, has made a "retreat from the word," as literary scholar George Steiner put it. In a 1961 *Kenyon Review* article, Steiner wrote, "It is, on the whole, true to say that until the seventeenth century the predominant bias and content of the natural sciences were descriptive." Mathematics used to be "anchored to the material conditions of experience," and so was largely susceptible to being expressed in ordinary language. But this changed with the advances of modern mathematicians such as Descartes, Newton, and Leibniz, whose work in geometry, algebra, and calculus helped to distance mathematical notation from ordinary language, such that the history of how mathematics is expressed has become "one of progressive untranslatability." It is easier to translate between Chinese and English—both express human experience, the vast majority of which is shared—than it is to translate advanced mathematics into a spoken language, because the world that mathematics expresses is theoretical and for the most part not available to our lived experience.

For example, whereas Euclid's geometry was written in simple prose intelligible to any literate layman, the non-Euclidean geometries developed in the nineteenth century can only be written using esoteric technical notation systems. This difference in linguistic expression—ordinary versus technical—reflects a difference between conceptions of space itself. One conception is derived from everyday experience; the other is of space as what is geometrically possible, even if impossible to depict in an intuitive way—and impossible precisely because of the constraints of space as we experience it. Whereas the drawings involved in proving Euclid's theorems are faithful representations of space according to ordinary experience (think of the Pythagorean theorem), the drawings for Lobachevski's or Riemann's geometries, for instance, look distorted, and one has to remind oneself constantly that in essential ways the images do not correspond to the mathematical demonstrations. The history of modern physics, shaped as it is by mathematics—as for instance Riemann's geometry is a key component of Einstein's theory of curved, four-dimensional spacetime—has also been one of increasing untranslatability. A rift has opened up between spoken, human language as such and the physicist's mathematical representation of the world.

Some physicists in the twentieth century have reflected on what this rift might mean for public understanding of physics. Oppenheimer commented at a 1959 conference that whereas eighteenth-century physics, astronomy, and mathematics were "not beyond the reach of laymen," today "we see a very different situation, an alienation between the world of science and the world of public discourse." Even scientists from different disciplines seem alienated from one another, he explains. The physicists sometimes fail to understand the chemists, and may even find the mathematicians' cutting-edge work foreign.

Elsewhere, Oppenheimer wrote that "many of the things that Newton's laws dealt with were reasonably accessible to common experience; they had been talked about in a way that made them part of intellectual life for two millennia." By contrast, quantum mechanics and the theory of relativity concern phenomena that simply are not available to lay people.

Another twentieth-century physicist, Philipp Frank, explained that "even the statements of Newtonian physics cannot really be formulated in common-sense language, but in the relativity and quantum theories the impossibility becomes obvious." For instance,

> in quantum theory the term "particle" is employed as a thing which has no precise position and velocity, and so is clearly incompatible with the full common-sense meaning of this word. I once asked Niels Bohr whether it would not be practical to eliminate the term "particle" completely from quantum theory. Bohr agreed that one could do so in the interest of unambiguity.

And yet, Frank said, the word continues to be used, not least because its meaning in physics still bears some resemblance to its everyday meaning. The fact that the two meanings are not identical does not necessarily impair the separate use of the word in either context—just as in any other discipline, familiar words often have technical meanings, which it is the task of the discipline to define. But the important point here is that the word "particle" as used in physics seems to resist accurate description in commonsense language. And so one of the most foundational building blocks, as it were, of the physicist's conception of the universe seems to escape our linguistic grasp.

This peculiar situation was well expressed by Bohr himself when he wrote that "by the very nature of the matter, we shall always have last recourse to a word picture, in which the words themselves are not further analyzed." Here is where the issue of translation comes back into focus. Because the mathematical description of the universe is ultimately untranslatable into words, the words we do use can refer to the mathematics in only a very rough manner.

Considering this incongruence—between what the math says and what the words say—it is no surprise that physicists often come up with imaginative and poetic ways of talking about the physical world, ways that try to capture as well as may be possible something that transcends verbal limitations. For example, writing about the conception of space according to quantum mechanics, Rovelli explains that space is

> made up of grains, or "atoms of space." ....The theory describes these "atoms of space" in mathematical form....They are called "loops," or rings, because they are linked to one another, forming a network of relations that weaves the texture of space, like the rings of a finely woven, immense chain mail.

The mixed metaphors, convoluted similes, and scare quotes indicate the difficulty of pressing into words what physics describes in mathematics. And although the string of images (or is it a web?) violates all possible poetic sensibilities, it illustrates the need for poetic, figurative depiction in place of literal description when talking about quantum mechanics. This seems lost on Rovelli, which may be why he tries to use poetic language in a literal, descriptive way, apparently unaware of the mess he's made. Rovelli again, now poeticizing the conception of time in quantum mechanics: "At the minute scale of the grains of space, the dance of nature does not take place to the rhythm of the baton of a single orchestral conductor, at a single tempo: every process dances independently with its neighbors, to its own rhythm."

This is altogether far from Bacon's ideal of precise, unambiguous, descriptive terms. Or is it reasonable to think, following his suggestion, that these poetic images are merely a temporary help to express difficult ideas, which over time we can replace with straightforward terms? Is the need for poetic expression here simply that Rovelli is translating abstruse technical terminology into language accessible to a wide readership?

Although it is surely right that poetic images serve popular science translation, even the physicists' terms of art themselves are sometimes more poetic than descriptive. Wilczek draws attention to John Wheeler's ingenuity for "striking phrases to describe physical ideas," although "describe" is here meant loosely. There is "black hole" and "Mass Without Mass," and Wheeler's "poetic way of describing" the essential idea in Einstein's general theory of relativity:

> Matter tells space-time how to curve.
> Space-time tells matter how to move.

Wilczek goes on to criticize this "poem," in which "'matter' is a little *too* poetic"—instead, it should say "energy-momentum."

Another memorable and creative word coinage comes from Murray Gell-Mann, who came up with the word "quark" for the constituents of protons and neutrons that he helped to discover. He recounts in *The Quark and the Jaguar* (1994) that he thought of the sound "kwork" first but did not settle on a spelling until reading these lines in James Joyce's *Finnegans Wake*: "Three quarks for Muster Mark! / Sure he hasn't got much of a bark," which led him into the following literary analysis:

> Since "quark" (meaning, for one thing, the cry of a gull) was clearly intended to rhyme with "Mark," as well as "bark" and other such words, I had to find an excuse to pronounce it as "kwork." .... Words in the text are typically drawn from several sources at once, like the "portmanteau words" in *Through the Looking Glass.* From time to time, phrases occur in the book that are partially determined by calls for drinks at the bar. I argued, therefore, that perhaps one of the multiple sources of the cry "Three quarks for Muster Mark" might be "Three quarts for Mister Mark," in which case the pronunciation "kwork" would not be totally unjustified.

He then goes on to explain that different quarks have different "flavors" and "colors," hastening to add that such terms have "no more to do with real color than flavor in this context has to do with the flavors of frozen yoghurt." (Although he does not mention this, "Quark" is indeed a dairy product in Germany and Switzerland.) And Rovelli, this time with a more sensitive ear, adds that "The force that 'glues' quarks inside protons and neutrons is generated by particles that physicists, with little sense of the ridiculous, call 'gluons.'"

There are other examples in physics of creative and poetic terms of art—dark energy, antimatter, strings, loops, spin foam, big bang, big bounce—that reflect how the verbal forms derived from ordinary human experience shape the accounts of the physical world that defy ordinary human experience.

The history of physics in the last century or so is vastly more complex than—and in some ways even the inverse of—the idea of Bacon and others that our understanding of nature progresses from cryptic, poetic expressions to clear and distinct terms. This is not to say that we are back where we started from in the *content* of our understanding, or that labels in contemporary physics don't have precise meanings, but that the *verbal form* of those labels is often much like the old: poetic images that tend to escape precise description in commonly intelligible terms. Bacon claimed that "as hieroglyphics were in use before writing, so were parables in use before arguments." Today, the hieroglyphics and the parables seem to be again very much in use. The language that is close to everyday human experience is not easily avoided and shapes even our farthest intellectual leaps away from the everyday.

The philosopher Nicholas Rescher captures the situation:

> It is instructive to contemplate...the hopeless difficulties encountered nowadays in the popularization of physics—of trying to characterize the implications of quantum theory and relativity theory for cosmology into the subscientific language of everyday life. A classic *obiter dictum* of Niels Bohr is relevant: "We must be clear that, when it comes to atoms, language can be used only as in poetry." ....Homo sapiens began his quest for knowledge in the realm of poetry. And in the end it seems that in basic respect we are destined to remain close to this starting point.

Twisting Words

Already widely known for its ineffability, there is one particular aspect of quantum theory that most clearly illustrates just how far out of reach the physicist's conception of the material universe now is from verbal expression—and thus how perplexing is the attempt to put the physicist's conception into words, and words no less through which the layperson is supposed to get some glimpse of the reality behind the veil of ordinary experience. This is the idea that, scientifically speaking, things don't exist, that objects are illusions, that every thing is only process, that ours is "a world of happenings, not of things," as Rovelli puts it. "As it seems to me...we must accept the idea that reality is only interaction," he writes. This idea is the basis of the 2007 book *Every Thing Must Go*, a collection of essays by philosophers who insist that modern science shows that all the objects of our ordinary experience—tables, baseballs, human beings—at a fundamental level do not really exist.

The obvious difficulty this thesis presents for verbal expression is that it would seem to make most nouns obsolete, including the nouns that were once thought to be ideal for scientific description—the ones that are clearly linked to things in the world. If no thing exists, it is difficult to imagine how one would begin to talk about reality. Although this is not an argument against the validity of the idea that relations are more fundamental than things, it should be a damper on any naïve optimism that this idea can be put into words in a straightforward way.

There is a famous precedent for the view that reality is only becoming and motion and flux: the philosophy of Heraclitus, most famously encapsulated in the statement that one cannot step into the same river twice. In Plato's *Theaetetus*, Socrates points to the difficulty the Heracliteans have of putting their philosophy into words, because they "must set down some different language, since now at least they don't have the words for their own hypothesis."

A different language has indeed been proposed, one that would avoid the supposed illusion that nouns refer to fixed things. In the 1980 book *Wholeness and the Implicate Order*, physicist David Bohm claimed that ordinary language depends too heavily on nouns. The subject–verb–object structure of sentences, nouns acting on nouns, tends "to divide things into separate entities, such entities being conceived of as essentially fixed and static in their nature." The problem with this separation of things is a fragmentation of thought in all areas of life, making impossible a sense of wholeness. "When this view is carried to its limit, one arrives at the prevailing scientific worldview, in which everything is regarded as ultimately constituted out of a set of basic particles of fixed nature." But modern physics, he argued, has shown that objects, even at the level of the most basic particles, are never fixed; in fact, they are not even really objects but abstractions from "on-going movements that are mutually dependent."

As an experiment intended to reveal this "inappropriateness" of common speech, Bohm proposed that instead of nouns, which help to cause fragmentation and confusion, we ought to try using verbs for building complex ideas from simple, concrete experience. For instance, to refer to the unified act of perception and mental apprehension, we might use the term "to vidate" (from the Latin *videre*, "to see"). From there, we can "re-vidate"—remember or recall; "di-vidate"—see things as separate; and so on. And so instead of speaking of accurate recollection, we will say, "to re-vidate is re-vidant." This new mode of language—Bohm called it the "rheomode," from the Greek word for "flow"—would reflect more accurately the truth that all is in flux, that understanding activity is the only sure way of understanding the world.

Bohm's idea is bizarre, but it usefully shows the problem of how to force into linguistic form the physicist's conception of nature as "thingless." Although such a language would reflect the flow-like status of the relations that physicists maintain are the fundamental constituents of reality, consider how difficult it would be to talk in a noun-less language about anything else besides the most fundamental material realities. Even in physics we would expect nuclear physicists to continue speaking of radioactive "elements," astrophysicists of "exoplanets," and so forth.

With these objections, we are probably taking Bohm's idea both too far and too seriously. He imagined that we would build nouns out of verbs, not avoid nouns altogether. But it is worth considering the point that scientific investigation, at least in most cases (perhaps in all), requires an everyday, commonsense perspective and language—one that includes things, and nouns to label them. We might even say that the spectacular success of modern physics is not least due to the kind of fragmentation that Bohm deplored—breaking up things into their constituent parts and labeling objects according to kinds, even past the point where one could still speak of their "thinghood." For instance, Wilczek reports that at conferences on high-energy physics, experimentalists "speak routinely of producing nonexistent particles (quarks, antiquarks, or gluons) and measuring their properties. It's become the standard language of the field."

The absurdity of the idea that our language should be made to suit flux theory—and the dire consequences this language might have on science itself—is creatively illustrated in a 1941 short story by Jorge Luis Borges. A certain language on the planet Tlön has no nouns and instead uses only verbs. For speakers of this tongue, "the world is not a concurrence of objects in space, but a heterogeneous series of independent acts." Where we would perceive things in motion, they only see motion, but no things. A rough translation of "the moon rose over the sea" in their language would be "upward beyond the constant flow there was moondling."

Borges imagines that with this language it would be almost impossible to think of anything as fixed or object-like, and so it "completely invalidates science," at least as we know it. Perceiving a series of events, these people would not be able to identify any objects (meaning nouns) as the underlying substrate connecting the events. For example, seeing first a smoke cloud, then a fire, and then a half-burning cigar would not lead one to imagine a cause-and-effect relation between objects; they would not be recognized as objects but only as chaotic movements. And so, Borges writes, "among the doctrines of Tlön, none has occasioned greater scandal than the doctrine of materialism," for the idea that any material stuff is at the bottom of the river of constant change is unsayable, and so virtually unthinkable and unintelligible.

This is of course fantasyland, not physics, and the notion that our thinking is fully constrained by the grammar of our language is questionable. But the point, to put this somewhat strangely, is that nouns have served physics very well and that forcing our language to fit the constraints of the flux idea isn't sensible. This also means, however, that—stuck as we are with nouns as basic building blocks of language—there remains an unbridgeable gap between the physicist's mathematical conception of material reality and our best approximation of that conception in speech.

The Limits of the Monolingual

We began with the idea that popular writing about physics is an act of translation, and we can now add to this that, in the case of physics dealing with fundamental material reality, all verbal language, not just popular, is at best a sort of rough translation, for which poetic images will often be more useful than strictly descriptive terms.

Like all translations, those from physics to words can be deceiving too. As the oft-quoted Italian saying has it, "*traduttore, traditore*"—"translator, traitor" (a case in point, since the pun doesn't work in English). We may be deceived, for instance, when we ignore that texts on physicists' conceptions of reality are in fact translations; that's easy to do, for by one way of judging, a translation should not sound like one. Or we may be deceived in thinking that our household familiarity with certain terms used in physics—for example, information, relativity, the uncertainty principle, particle—measures up to real understanding of what these terms mean to the experts. George Steiner warns that

> It is arrogant, if not irresponsible, to invoke such basic notions in our present model of the universe as quanta, the indeterminacy principle, the relativity constant, or the lack of parity in so-called weak interactions of atomic particles, if one cannot do so in the language appropriate to them—that is to say, in mathematical terms. Without it, such words are phantasms to deck out the pretense of philosophers or journalists.

In a sense, this is a danger whenever we try to understand and talk about something beyond our current intellectual reach—we are easily conceited about how much we understand, especially when we rely only on popularly consumable translations.

But there is an additional kind of pretension we should be wary of when talking about physics: the belief that the words of physicists and science writers about what the physical world is like simply *are* descriptions of the real world. Perhaps these words are decorated here and there with a helpful metaphor or analogy to get difficult concepts across; but, that poetry aside, we often think these descriptions neatly map onto the world and thus present a clear and illusion-free view of reality. It is a belief that is easily derived from a way of thinking about scientific language as the ideal of true understanding, and about words as unambiguously linked to things and processes. That ideal doesn't seem to apply well to the physics of fundamental material reality. At best, popular physics texts are approximate renderings of the meanings and implications of mathematical models and theories. (And what the mathematics precisely mean, and how they do or don't describe the world, is yet another set of complications that popular science writing routinely ignores even though they have long been subjects of philosophical fisticuffs.)

All this is more than a general lesson about intellectual humility; it is also a lesson about the folly of thinking that the language of physics is the only one that discloses ultimate truth about the world. Reflecting on the difficulties involved in speaking about fundamental physics suggests that, however useful to science the ideal of clearly defined descriptive terms is, in the end we still have to rely on language that is closer to our everyday ways of speaking—rich in imprecise words, in poetic images and rough analogies, metaphors and gestures.

Different languages open up different ways of apprehending the world and saying true things about it. This is why translations often need to import foreign words, ideas, and ways of thinking to render the original in the new context, and some distortion is often inevitable even in the best possible translations. But in those instances, only the person who knows both languages can tell how much of the original is retained and how much is lost. By contrast, as philosopher Stephen R. L. Clark has written, "the fate of the monolingual is to find things 'obvious' that aren't *true*, and to be prevented from transcending their own tongue"—a tongue that may be incapable of expressing certain truths, as English, for example, is unable to express the full intricacies of Japanese social ranks, or everyday language is unable to express the full intricacies of fundamental physics.

For physics texts, the fate of the monolingual applies to two kinds of people. On the one hand is the consumer of popular physics texts who doesn't know mathematical physics and thus fails to see what's lost in translation. On the other hand is the person Clark actually has in mind, the believer in scientism: The fate of the monolingual "seems to be befalling recent scienticists [adherents of scientism], who think that nothing which is excluded from 'scientific language' can be real."

What we need is a richer appreciation for the boundless ways in which different languages—including everyday speech in contrast to scientific speech—are equipped differently to depict the world and to offer ways of making it intelligible. And those of us who depend on translations also need to learn to transcend our own tongue. A comparison to literary translation between very different languages is helpful here. The Japanese novelist Minae Mizumura has written, in *The Fall of Language in the Age of English*, about how some popular Japanese writers omit the linguistic and cultural nuances that are traditionally part of good writing in their language, because, anticipating translation into English (and thus wider success), writers avoid those nuances that English does not capture well—like the California roll that makes sushi palatable to the uninitiated. While we should be deeply grateful for the labors of those who make strange worlds—whether of culture, cuisine, or mathematical physics—more easily accessible, we should neither confuse ease of access with the availability of intimate knowledge, nor let the cultural dominance of one language over another obscure the full riches of both.

The authority of physics is entirely justified for the kinds of explanations and powers it affords. But the idea that the language of physics alone speaks the ultimate truth about the world, dispelling the illusions produced by our everyday experience, for instance of space and time, or of consciousness, seems difficult to defend when that language itself depends on ways of speaking that belong fully to everyday experience. Talk of illusions is surely overrated and often no more than sensationalistic silliness. It would be wiser to say that the physical world, whatever it is like when expressed in the full complexity of mathematical physics, is unlike what it seems to us. And that is the point: The physical world isn't like that *to us*, which means that if it matters that we understand human experience as fully as we might, including how we shape our personal, moral, and political lives, then the hope that mathematical physics alone discloses ultimate reality is misguided. This is so even while—and this is no small thing—physics offers one of the richest opportunities for wonder, to which the most deeply human response, besides seeking to understand, may well be either poetry or silent awe.