FAITH IN MATH

This grand book, the universe … is written in the language of mathematics.

Galileo Galilei (1623)

The theoretical physicist's picture of the world … demands the highest possible standard of rigorous precision in the description of relations, such as only the use of mathematical language can give.

Albert Einstein (1918)

Since the mathematicians have invaded the theory of relativity, I do not understand it myself anymore.

Albert Einstein (1949)

It is mathematics, more than anything else, that is responsible for the obscurity that surrounds the creative processes of theoretical physics.

Lee Smolin (1997)

Physicists today are trained to calculate numbers rather than analyse conceptual arguments, and their verbal interpretations of their own theories are often unreliable.

Jay Kennedy (2003)

The equations of string theory place mathematical restrictions on the geometry of the extra dimensions, requiring them to belong to a particular class called Calabi-Yau shapes.

Brian Greene (2011)

Frank's bent is far from mathematical to say the least. He hears the word, he breaks into a sweat, his eyes take on a wild look. I tell him we won't *do* the math, we'll only talk and I will write the notes. He's not convinced. Why, he wants to know, would we speak of it? Well, math is how the physicist communes with heaven, or rather with the world. Not all that's math is physics but all physics in the end is math.

Certain specialties, like symmetries, geometries, topologies and numbers, turn out to be fertile soil. They are where physicists grow physics. It's not only, I explain, that math's convenient. Nor even that it can be made precise. It's that it seems to be the language of the universe. And so to physicists it is supremely real.

As usual I try to ease him into it with history. How the idea first arose that arcane symbols may describe the world is lost in time. Numbers may have been the first, the counting words so potent, used in commerce. The Western number system, modified by Arab culture, may hail from Pakistan about 4,000 years ago.

Geometries arise in the Mid-East around 3000 BCE. The ancients knew a thing that might surprise students today and yet is pivotal to physics: Geometries are many. Schools teach Euclid's, dating to about 300 BCE. Indeed, as Barrow says, for more than two thousand years, 'Euclid's geometry was believed to be true—a precise description of reality … it provided important evidence that human thought could penetrate the nature of ultimate truth.'

It's a geometry he says that he remembers, but remembers only that he took it for a while. He never knew it came from Euclid. Like Euclid he assumes it's real. He hasn't heard of physics proving Euclid to be wrong.

But that comes later. Greek and Indian and various Islamic scholars explore numbers in the first millennium CE. In the second half of that millennium, Islamic thinkers find relationships between geometries and other branches such as algebra. In Europe, number theory starts to build on these foundations in the 1500s.

Geometries and numbers, two of the roots of physics, join hands early. Around 500 BCE, Pythagoras and followers discover secret numbers for right-angled triangles. They have mystic roots in integers (a fancy name for natural numbers—such as 1, 2, 3 . . .). They find the third side of a triangle with right-angled sides of 3 and 4 is 5 units long. *Exactly* 5. Likewise 5, 12, 13. They find many more such triples. Much later others find these numbers work with only one geometry—the one devised by Euclid. It soon achieves a near-monopoly. Why? Well, it seems to relate to the real world.

Once again it's Einstein who destroys the pretty picture. In Euclidean geometry the angles of a triangle add to exactly 180 degrees. Einstein says the angles of real triangles may add to just a little less, or maybe a little more. How much depends upon their size. In fact it is absurdly small for less-than-cosmic triangles. It seems an odd coincidence: If not exact, why is it so close? This question is tied up with several cosmic problems. The fact it's not exact seems to encode some basic truth about the universe. I tell him it's a code that he may need to break. He rolls his eyes.

This math stands apart from early physics until Newton comes along. He plants math firmly on the physics map. Or is it vice versa? Even so, 'til 1905 the intrigue of math is not enough to give it traction to refashion physics. Jeans says that, in that year, 'the study of the inner working of nature passed from the engineer-scientist to the mathematician.'

I'm just getting into stride with this when she walks in the door. She's just back from Cambridge. So she says. It takes minutes more of chat before it's clear she means the one in England. I don't know what it is about her, why she ticks me off. She's unfailingly polite. She's even pleasant. She signs the checks. She pays the bills. She lets me work on what I want. She doesn't *have* to tell me what she's really all about.

Today right off she wants to know what I have on black holes. The answer is, not much. To play it safe I say that I have nothing yet. I'll have to do it soon though. Why? Well, some clues seem to revolve around black holes. And so, it seems, does she. Of course there are lots of reasons for a trip to Cambridge. The big one is a university. Lots to see there too. One of them is Stephen Hawking. The king of black hole country. I don't imagine she'd have *seen* him. After all, what does she have that would be worth his time? Not money. He sold 10 million copies of one book and then wrote more; he doesn't need her money. And if she saw him, why would she be asking *me* about black holes? But she was there. Some people merely marvel at coincidences; some of them will never know what hit them. Memo to file: Check out black holes.

She goes just as abruptly as she came. He seems distracted as I try to take him back to faith in math. Physicists are busy calculating properties of . . . what? The answer seems to me, is: They are busy letting calculations pick the 'what'.

As Penrose puts it, 'To mathematicians … mathematics is not just a cultural activity that we ourselves have created, but it has a life of its own, and much of it finds an amazing harmony with the physical universe.' Even Einstein says in his heyday that 'the creative principle resides in mathematics.' Yet in later years Einstein is not a fan of what Penrose will later call 'mathematically driven fundamental physics.' Einstein sees math as a tool to explore concepts that are grounded in experience. And if faith in math's a rule, Einstein offers some exceptions. On occasion he ignores the math or fiddles it to fit his preconceptions.

The famous case is when he sexes up GR's equations with a term designed to offset gravity so that he gets to the unchanging universe that he expects. Five years later, after reading Friedmann's paper showing how these same equations *could* lead to an expanding universe, Einstein claims—a claim he soon retracts—that Friedmann's math is wrong. Farrell says,

> Einstein's hasty objection and retraction concerning Friedmann's work seem to suggest a stubbornness based on more than simply what he knew of the stellar velocities of the time. They suggest a prejudice, an ingrown view of the cosmos inherited but never really questioned.

But Farrell goes on to acknowledge, 'There never had been reason to question it until the advent of Einstein's theory.' So, when push comes to shove, for Einstein his ideas are paramount. Math can't dictate them; it should express them.

In his later years at Princeton, Einstein pursues relentlessly an unproductive passion for developing a unified field theory—a Theory of Everything that he believes will bridge the New Divide. His efforts are ignored or even ridiculed as QM's simply-calculate approach yields rich rewards. In this era math takes firm control of physics. Though the philosophy-first approach epitomized by Einstein sowed the seeds of scientific revolution, his critics reap the harvest. Today a later generation sees harvests fail. It seems math, the faithful servant, is a less than perfect master.

Nor is it a perfect servant. Often it can't meet the present need. Baez for example speaks of need for math 'that allows one to speak of processes between processes between processes.'

Such math, he says, could come to grips with what is real. To me it sounds like LISP, my favorite computer language. To me, too, math's symbols camouflage a deeper weakness: In the end they all depend on words.

It's Friday and we are, for different reasons, both mathed-out. As he takes off early for the weekend I suggest he could read Smolin. He surprises me; he takes the book.