The *Next* Ultimate Theory

What will the ultimate theory
(or at least the next one) be like?

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by **MARC KAUFMAN**

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The late, great Richard Feynman leans back in his chair and suggests an analogy to help us appreciate how scientists try to understand the world around them.

Imagine you're watching the Gods play chess, he invites us. You've never heard of the game, but you are allowed to observe the board in order to discern the rules. As the game unfolds, something becomes clear about the bishop.

OLAF DREYER
MIT

You're not sure why, but when it moves, the bishop always remains on the same color square on which it began the game. Then you discover another rule that instantly gives you a deeper understanding of the first: bishops must move on a diagonal. That is why they always maintain their color.

Once you begin to appreciate the more fundamental laws, Feynman says in a 1981 interview for the television program *BBC Horizon*, hands clasped behind his head, a smile playing across his face, "Then things can happen." Building on previous insights, you can observe and investigate unexpected and complex new phenomenon as you continue to deepen your understanding of the game.

And so it goes until something happens that revolutionizes your comprehension of one or more previous laws. A pawn manages to advance to the opposite end of the board and is replaced by a bishop. But this bishop doesn't move only on the diagonal – it moves like a queen. So the bishop doesn't *always* maintain its color after all. Again, your understanding of chess expands.

Feynman suggests that a novice's observation and investigation of the rules of chess is analogous to scientists' investigation of the laws of the Universe – both think they understand the laws until something unexpected happens and forces them to reconsider, often resulting in a richer set of rules. Physicists are "always trying to investigate those things in which we don't understand the conclusions," Feynman says. And "the thing that doesn't fit is the thing that's the most interesting. The part that doesn't go according to what you'd expect."

> Not only are our current theories not good enough, they stink.
>
> \- *Olaf Dreyer*

But unlike chess, in which the discovery of each successive rule makes the game appear increasingly complicated, Feynman says that in physics, "every once in a while we have these integrations in which everything is pulled together in a unification which turns out to be simpler than it looked before."

Indeed, when these unifying moments have occurred, they have revolutionized our understanding of the natural world – with the weight of the achievement leaving us with the feeling that we have, finally, arrived at the best, fullest, simplest explanation: *An ultimate theory*.

Yet, like Einstein before him and like every scientist since his death in 1988, the discovery of a true "ultimate theory" – one that explains literally everything – escaped Feynman. Discouraging as that may be, it has not stopped us from continuing the search.

Ultimate is in the Eye of the Beholder

The very idea that we are in search of an ultimate theory obviously presupposes that the best existing science is not ultimate enough.

GARRETT LISI
Independent

And that, according to MIT physicist Olaf Dreyer, is putting it kindly. "Not only are our current theories not good enough," he says, "They stink. They have been so for most of the last century." The main problem is that quantum mechanics and gravity currently are not compatible, Dreyer says. "This is outrageous and needs to be addressed."

"We have great theories for describing elementary particle physics and for describing gravitation," explains freelance physicist and surfer Garrett Lisi, referring to quantum mechanics and general relativity respectively. "But these theories fail when we try to use them to describe how gravitation acts at the tiny scales and high energies of particle physics."

"What we have isn't physical enough or even self-consistent," professor emeritus of physics at Georgia Tech David Ritz Finkelstein adds. "It assumes various continua that are beyond experimental verification, and then does weird arithmetic to get finite answers."

Physicist Rodolfo Gambini from the Universidad de la Republica in Uruguay agrees. "All present theories present signs of incompleteness that manifest in the appearance of singularities or infinites," he says.

DAVID FINKELSTEIN
Georgia Institute of Technology, Emeritus

"There are certainly things that happen in the universe at these scales, so there must be some way of describing it," continues Lisi. "There's something going on, but we don't know what – this is the biggest challenge in physics."

Still, our current understanding of the physical world is more than capable of accurately and satisfyingly describing anything and everything we are likely to run up against in our lifetimes. To use Feynman's metaphor, it's hard to imagine stumbling upon a "chess move" that modern physics cannot explain with a known rule. It's not that we *need* to know how it all works in order to explain our daily reality; it's more that we *want* to know.

"The quest for an ultimate theory is philosophically rather than practically motivated," Lisi acknowledges.

A Theory Only a Mother Could Love

Let's suppose a true "ultimate theory" exists: What will it look like and how will it operate?

Ideas were batted around at FQXi's Iceland Conference last summer. While many agreed it was refreshing to discuss the questions in the hot springs of Reykjavik, they didn't always agree on the answers. To wit, will the theory will be "simple"?

"So far, the smaller things are in scale, the simpler the constituents are: Organisms to molecules to atoms to subatomic particles – with a reduction in complexity at each step," Lisi says. "So it seems reasonable that the next step be simpler still."

But Gambini has other ideas. "Quantum field theories and general relativity are highly complicated theories," he says. "I do not expect to end up with a simpler theory." Gambini thinks the ultimate theory will allow us "to make predictions about our Universe in exceptional regimes," such as black holes, the Big Bang, and perhaps even in other Universes. But because these regimes are by definition unobservable, he says, "much of the certainty about the validity of the theory would result from its elegance and internal coherence and consistency as well as from some crucial experiments."

"I hope the basic idea will be simple whereas the actual calculations will be complicated," says Dreyer diplomatically, adding that he feels similarly divided about the attractiveness of the potential theory in question – that the physics behind it are likely to be beautiful, but the implementation rather ugly.

"Its mother will find it beautiful," Finkelstein jokes. "Its initial audience will find it funny until it makes useful predictions. Then many students will find it boring. 'Are we responsible for that?' they will ask."

Lisi arrives at a similar conclusion, albeit independently of Finkelstein. "We live in a beautiful universe – so any successful theory will necessarily be beautiful; but perhaps only to its mother," he says. "And it's certainly going to be funny. If it were boring, we would have figured it out already."

"Boring? I don't think so," Dreyer concurs. "Why would I look for it then?"

All In The Family

So the ultimate theory may or may not be simple, and it will definitely not be boring. But what relationship will it have to current theories?

"Since quantum mechanics is such a successful description of reality, any theory that supersedes it will have to reduce to current descriptions of quantum mechanics" – at least to some extent, says Lisi.

For his part, Dreyer thinks that while there may be changes in the way we interpret the basic states of quantum mechanics, we will retain basic parts of the existing theory: linearity and the superposition principle, for example.

Gambini goes even further. "In my view the theory not only will be quantum mechanical but it will be exclusively quantum mechanical," he says. "I think that even though this theory will preserve most of the basic postulates of quantum mechanics, it will not have [quantum mechanics'] current form because both the inclusion of gravity and full relationality will require introducing important modifications."

RODOLFO GAMBINI
Universidad de la Republica, Uruguay

"The theory I am looking for would be more quantum than quantum theory and more relativistic than relativity, and therefore even less ultimate than either, if it turns out to exist," Finkelstein cautions.

And Then What?

If scientists one day discover a theory that integrates quantum mechanics and general relativity, Lisi wonders, Where would that leave physics?

"Strictly speaking, if one [were] able to develop a theory that provides a precise description of all known or conceivable physical processes – free of inconsistencies like the ones present in the interface of quantum mechanics and general relativity – [then] one should consider that physics has reached its final goal and provided a complete understanding of the physical phenomena," says Gambini. "[But] I cannot conceive that human beings will be able to construct a theory able to satisfy completely our understanding."

After all, the "next" ultimate theory, no matter how promising it might seem, may also turn out to be somewhat less than ultimate. Just around the corner, there may be a more simple explanation, waiting to unify a more disparate set of rules and afford yet a deeper, richer understanding of the world around us. Or perhaps Feynman's chess Gods are simply keeping our thirst for knowledge in check.

"Every theory has an expiration date on the bottom," Finkelstein reminds us, "though it may be hard to find."