PHYSICS

Fundamental Feynman

An account of the physicist's work reminds **Leonard Mlodinow** of the gulf between theory and experiment.

In 1981, shortly after I arrived in the physics department at the California Institute of Technology in Pasadena, I heard a strong voice resonating down the corridor: "Hey Schwarz, how many dimensions are you in today?" The answer then was 10; it was once 26; it is now 11. Richard Feynman, who was teasing John Schwarz — one of the founders of string theory — didn't think much of any theory in which it wasn't four, for that is all we observe.

Quantum Man, by theoretical physicist Lawrence Krauss, focuses on the intimate connection that Feynman, like other physicists of his era, felt should exist between theories and experimental data. Writing to his third wife Gweneth from a gravitation and cosmology conference in Warsaw in 1962, he complained: "Because there are no experiments, this field is not an active one, so few of the best men are doing work in it. The result is that there are a host of dopes here (126) and it is not good for my blood pressure."

Today, gravitation and cosmology attract many of the best minds, who between them have produced so many unproven and competing theories of the multiverse that string theorist Brian Greene was able to write a long, popular account of them in *The Hidden Reality* (Allen Lane, 2011). Meanwhile, most scientists who study that cousin of cosmology, elementary particle theory, work in string theory despite its undetected dimensions and other apparent disconnects with reality, issues that current experiments cannot resolve.

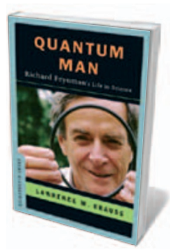
By contrast, as Krauss recounts, when Feynman first presented his then-incomplete ideas on quantum electrodynamics (QED) describing the interaction between light and matter to the physics community in the late 1940s, he had "calculated almost every quantity one could calculate in QED" to ensure his results agreed with other methods and experiment as far as was known. Much of the book concerns the intellectual journey that culminated in that work — a reformulation of quantum theory itself. It is a welcome addition to the shelf of Feynman biographies.

The story begins at Princeton University in New Jersey, with Feynman "in love" with the problem of the self-energy of the electron. Because like charges repel, each portion of a ball of negative charge exerts a repulsive force on every other portion. As a result, a ball of charge has a certain electric energy associated with it. The problem is, an electron is a point particle, but when you shrink the ball down to a single point, the repulsive energy becomes infinite.

Feynman thought that infinity had its roots in the way electromagnetic theory was formulated. This line of reasoning led him to recast the theory of electromagnetism in terms of an 'action principle', an exotic mathematical form that involves only the paths of charged particles over time, with no need to consider electric and magnetic fields. But the importance of what is now called Wheeler–Feynman electrodynamics (also named after US physicist John Wheeler) lies not in the theory itself, but in what it inspired Feynman to seek: a way to develop quantum mechanics around an action principle.

Size Matters: *Large Petri Test 3* (2011) by Klari Reis.

COURTESY OF THE ARTIST



Quantum Man: Richard Feynman's Life in Science
LAWRENCE M. KRAUSS
W. W. Norton: 2011. 368 pp. $24.95, £19.99

Feynman proposed a revolutionary new understanding of quantum reality. Imagine a particle that moves through some point A. According to classical physics, as it continues on its way, the particle will follow a definite path. Now consider another point, B. If B is positioned properly, the particle will eventually arrive there, but if B is located off the path, the particle won't. According to Feynman, the key difference in quantum theory is that the particle does not follow the classical path, or any single path. Rather, it samples every path connecting A and B, collecting a number called a phase for each one. Each of these, in concert, determines the probability that the particle will be detected at B. This novel approach, called the path integral or sum over paths, yields predictions equivalent to those of traditional quantum mechanics. Yet, as Feynman wrote, even if different theories are equivalent, "they are not psychologically identical when trying to move from that base into the unknown", meaning that they lead to different mental pictures, which can suggest different new ideas.

The unknown arena that Feynman moved into was the issue of how to fit quantum mechanics and special relativity into a single theory (we still don't know how to do this for general relativity, although string theory is a candidate). That synthesis, when applied to the electromagnetic force, is QED. In those days, QED, like string theory today, was a hard theory to make sense of. Quantum-physics pioneer Wolfgang Pauli wrote: "The risk is very great that the entire affair loses touch with physics and degenerates into pure mathematics." But in this case, Krauss points out, there were plenty of experimental data to guide and inspire Feynman, and after years of work and thousands of pages of calculations, he built a consistent and infinity-free theory

NEW IN PAPERBACK

Highlights of this season's releases

Perfect Rigor: A Genius and the Mathematical Breakthrough of the Century
Masha Gessen (Icon Books, 2011; £14.99)
In 2002, reclusive mathematician Grigory Perelman solved the Poincaré conjecture, one of the world's greatest intellectual puzzles. Shunning all publicity, he refused to accept the prestigious Fields Medal for his achievement and vanished from the public gaze. Journalist Masha Gessen attempts to discover more about him by travelling to Russia to interview Perelman's colleagues and teachers and discussing his behaviour with psychologists.

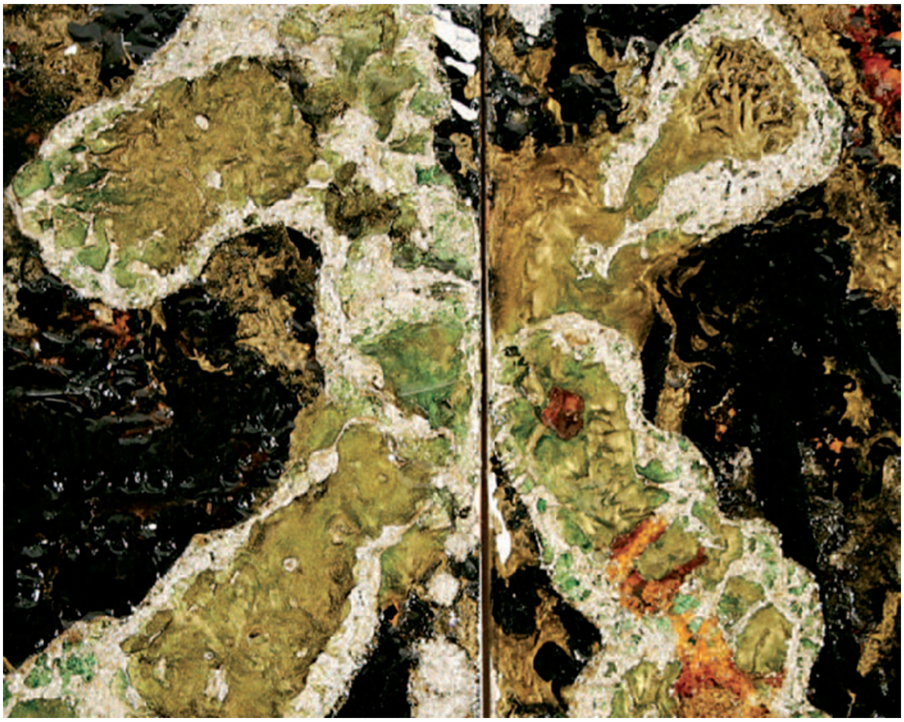
of QED. The result was so powerful that, according to US-based physicist Freeman Dyson, Feynman could do a calculation that once took several months "in half an hour" on the blackboard.

When he won his Nobel prize in 1965, Feynman felt his methods were merely useful, not profound. Today, his approach is considered a more fundamental way to look at quantum theory than the formulations of its founders, such as Niels Bohr, Werner Heisenberg and Erwin Schrödinger. It is the basis of how physicists think about particles interacting, exchanging carriers of force, fluctuating in and out of existence. It is also, ironically, the basic tool of both string theory and quantum cosmology.

Krauss does a good job of imparting Feynman's fascination with all physical phenomena, and goes on to describe Feynman's later groundbreaking work in other fields — on the weak interactions, the theory of liquid helium and his parton model, which provided evidence for the existence of quarks. Intertwined with the physics are snippets of Feynman's personal life, including his habit of working on physics in a strip club, and his undying love for his first wife Arline Greenbaum, who died from tuberculosis in 1945, just a few years after they were married.

As Krauss acknowledges, the book contains little that is new. Jagdish Mehra's *The Beat of a Different Drum* (Clarendon Press, 1994) is a far more detailed account of Feynman's science, equations and all; and James Gleick's best-seller *Genius* (Little, Brown, 1992) covers Feynman's personal life in greater depth. Still, I found the account of Feynman's hard work, passion and discoveries inspirational, and, for a physicist at least, good bedtime reading. For those without a strong physics background, however, the prose can be tough going, especially the more technical passages. Personally, I love being talked to that way. ■

Leonard Mlodinow *is author of* The Grand Design *(co-authored with Stephen Hawking),* The Drunkard's Walk *and* Feynman's Rainbow.
e-mail: len@caltech.edu



COURTESY OF THE ARTISTS AND JAYJAY, SACRAMENTO, CALIFORNIA

***Size Matters*: Detail from *Figure 6* (2008) by Ian Harvey and Koo Kyung Sook.**

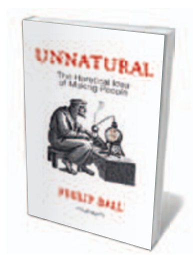
BIOTECHNOLOGY

Making people

Today's wariness of reproductive technologies stems from myths, legends and Hollywood, finds **Chris Mason**.

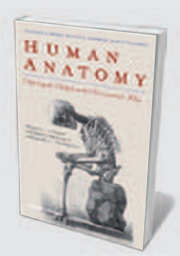
Stem cells, cloning, regeneration and life extension are frequently in the news. When they are, the media often resort to sensationalist clichés — invoking Frankenstein to conjure up a stereotypical mad scientist 'playing God' by creating out-of-control monsters. Whereas the creation of non-human artificial life, such as Craig Venter's engineered microbes, gets a mixed press, the making of humans is invariably controversial. Clearly, human life has a special moral status.

In *Unnatural*, science writer Philip Ball explores the history of our fascination with — and fear of — creating artificial people, from ancient folklore to today. Tracing a clear path



Unnatural: The Heretical Idea of Making People
PHILIP BALL
Bodley Head: 2011. 384 pp. £20

from medieval alchemists' homunculi to routine assisted conception is a feat. Through his impeccable research, Ball successfully argues that the tenacious myths of the past that surround the making of people or 'anthropoeia' (his coinage) affect life-science research today.



Human Anatomy: Depicting the Body from the Renaissance to Today
Benjamin A. Rifkin, Michael J. Ackerman and Judith Folkenberg (Thames & Hudson, 2011; £19.95)
This beautifully produced book presents more than 500 years of anatomical illustration. It charts how our knowledge about the body has changed along with our interpretation of what we see within it.

Wetware: A Computer in Every Living Cell
Dennis Bray (Yale Univ. Press, 2011; $18)
By treating a single-celled organism as a computational system, biologist Dennis Bray explains how it balances internal chemistry, responds to light and hunts prey — all without a nervous system. He sees cells as unique molecular circuits that perform logical operations.