NATURE|Vol 438|22/29 December 2005

more elusive and can change as new facts or ideas emerge.

Krauss's book is well written for a general audience and puts the scientific advances into a historical and philosophical context while keeping the technicalities under control. After a rapid overview of the past it focuses on the current aim of combining the two fundamental theories of twentieth-century physics: Einstein's general theory of relativity, and quantum mechanics, which between them deal with the very large and the very small. The need to unify these two theories is entirely aesthetic; there seems to be little need from the point of view of the experimentalist.

Over the past few decades, string theory has emerged as a serious contender to be such a unified theory. It involves extra dimensions galore: not just Einstein's four, or the five that also incorporates electromagnetism, but a total of 10 or 11. The extra dimensions are viewed as very small and curled up, so that, for most purposes, we are not aware of them. They only manifest themselves at very high energies, of the kind encountered in particle accelerators. Moreover, these extra dimensions are constrained by very precise symmetry requirements. The upshot of this is that string theorists can exhibit plausible models of a unified Universe, but unfortunately they cannot explain why we inhabit a particular one.

The mathematics involved in string theory is quite remarkable by any standards. In subtlety and sophistication it vastly exceeds previous uses of mathematics in physical theories. Almost every part of contemporary mathematics is involved somewhere in the story. Even more remarkable is that string theory has led to a whole host of amazing results in mathematics in areas that seem far removed from physics. To many this indicates that string theory must be on the right track. But Krauss is not a mathematician, so perhaps he is unaware of all this mathematical success, or maybe he discounts it as irrelevant. Time will tell. ■

Michael Atiyah is president of the Royal Society of Edinburgh, 22–26 George Street, Edinburgh EH2 2PG, UK.

Bitesize breakthroughs

The Discoveries: Great Breakthroughs in 20th Century Science Including the Original Papers
by Alan Lightman
Pantheon: 2005. 576 pp. $32.50

Graham Farmelo

Tapas are one of the greatest pleasures of Spain. These delicious snacks and appetizers are one of the foundations of the country's cuisine. Tapas-style books are becoming common too, as the average attention span of modern readers falls by the year. Here we have a promising science book in the genre, *The Discoveries*, a collection of short pieces on 25 of the best research papers of twentieth-century science.

It is an appealing idea, all the more attractive in this case for being prepared by the much-admired writer Alan Lightman, a physicist and adjunct professor of humanities at Massachusetts Institute of Technology. The author of three well-crafted novels, several popular-science books and many elegantly written essays, he is well qualified to achieve his ambitious aim of providing an insightful overview of modern science.

In his introduction, Lightman says that he sought to find the patterns of discovery, and to compare their discoverers and the different styles of working and thinking among leading scientists. He spent six months consulting widely before he made his final selection of discoveries. In his description at the end of the process, he is winningly open about his passion for science: "I held the stack of twenty-five papers in my arms, a century of scientific thought. My eyes filled with the tears."

Any selection of science's 'greatest hits' is bound to be controversial. But it seems to me that Lightman's choice is reasonable, if rather biased towards physics. He includes papers on quantum theory, Einstein's special (but not general) theory of relativity, nuclear physics, cosmology, Linus Pauling's pioneering paper on the chemical bond, Alexander Fleming's discovery of penicillin, Barbara McClintock's jumping genes, the structures of DNA and haemoglobin, and the first demonstration of genetic engineering. The most striking omission is a paper on plate tectonics, one of the few authentic revolutions of modern science.

The greatest challenge for Lightman is to give substance to his claim that "the first reports of the great discoveries of science are works of art", an assertion often made but rarely demonstrated. He makes it especially difficult for himself, as instead of giving an overview of the works' literary qualities, he introduces each paper (or sometimes a pair of papers) separately. The result is that the book is a series of 22 essays, each followed by the paper or papers that he has discussed. He reproduces some of them in full, but sensibly cuts the rest of them — a few by as much as two-thirds, others by only a fifth. The research papers are all in English, Lightman having found lucid translations of the seven papers in his selection that were originally written in German.

The physics-related chapters are, predictably, the most accomplished. Best of all is his essay on Hubble's law, which led to the realization that the Universe is expanding. It opens like a novel, on a chilly evening in the late 1920s, the sky "a deep purple gash flecked with stars". Lightman then paints a vivid picture of Edwin Hubble and explains why the discovery made such an impact. The problem is that he does much the same for all the other topics too, so the book is somewhat formulaic and repetitive. As one would expect of this author, the writing is unfailingly clear, but it disappointingly lacks his usual grace and style. Most of his explanations are surprisingly lacking in flair, and are little better than those conventionally served up elsewhere. Nor is the style especially pleasing: I would never have expected this most elegant of science writers, for example, to introduce Max Planck's ideas on quantization to a lay audience by referring to "elemental vibrating resonators".

I had hoped Lightman would persuade me that the finest scientific papers are often great art. Alas, it was not to be. I found myself guiltily flicking through the papers that are outside

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Steven Weinberg (right) won the 1979 physics Nobel with Sheldon Glashow (left) and Abdus Salam.

my bailiwick in physics, getting impatient with the technicalities. Lightman's introductions rarely gave me an appetite for unfamiliar fare: a bite or two was quite enough. I suspect that non-physicists will feel the same when they come across the three-line master formula at the heart of Steven Weinberg's unified theory of electromagnetism. They will not, I fear, have been much encouraged to persevere by Lightman's comment: "Even without knowledge of any of the symbols or their meanings, one must be impressed" by the formula's "economy and power". Some hope.

I have long been an admirer of Lightman, and was expecting *The Discoveries* to be an elegant and palatable introduction to modern science. Sadly, it is instead an indigestible and tedious read that I believe will have only limited appeal. One of the most creative chefs of science writing has shown that tapas are not his forte. ■

Graham Farmelo is a senior research fellow at the Science Museum, South Kensington, London SW7 2DD, UK.

A Titan of physics

Huygens: The Man Behind the Principle
by C. D. Andriesse
Cambridge University Press: 2005. 360 pp. £55

Owen Gingerich

Had Isaac Newton never lived, Christiaan Huygens would have iconic status for characterizing physical science in the second half of the seventeenth century. Like Newton, Huygens made enormous contributions in mathematics, mechanics and optics. He anticipated Newton in finding the formula for acceleration in the case of circular motion and brilliantly used it to determine the value of the constant of gravitational acceleration, *g*. He invented the pendulum clock, correctly interpreted the rings of Saturn, found the formula of the catenary curve adopted by a chain fixed at each end, and enunciated the fundamental principle of the wave motion of light.

Huygens was born in Holland in 1629, the second son of a domineering father, Constantijn, who was both a poet and a government diplomat. Christiaan's older brother, also named Constantijn, became a military officer and worked both independently and cooperatively with his younger sibling in making telescope lenses. In 1666, Christiaan, with his reputation as a mathematician already well established, went to Paris to play a leading role in the formation of Louis XIV's new Académie des Sciences. But in 1681, following the death of the minister Jean-Baptiste Colbert, whose patronage had energized the academy, Huygens was no longer welcome in France as the country turned against the Protestants.

In 1661 Huygens had visited London, meeting Robert Boyle and Robert Hooke, where he observed a transit of Mercury across the face of the Sun. In 1689, around the time of William of Orange's coronation as king of England, he again visited London, where he met Newton and Edmond Halley at a meeting of the Royal Society. There was, however, little love lost between Newton and Huygens.

Unlike Newton, who has an abundance of substantial biographies, accounts in English on the life and works of Huygens have been few and far from adequate. This biography by C. D. Andriesse, a physicist at Utrecht University, brings a wealth of newly translated information, making it the richest source of information in English about the seventeenth-century Dutch polymath. The book makes ample use of Huygens' surviving correspondence, diaries and notebooks, as well as his published volumes. Huygens was a somewhat erratic publisher, often holding back works for many years (and thus occasionally losing priority), so having access to the manuscripts was an essential part of this project.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Christiaan Huygens emerges from Isaac Newton's shadow.

AKG-IMAGES/NIMATALLAH

Andriesse's book is a fascinating account, but is by no means an easy read. The flow is interrupted from time to time by technical interludes that explain, for example, Huygens' work with musical temperaments or the production of an isochronous pendulum. These require the reader to be familiar with terms such as 'tonic' or 'evolute'. However, such sections can be easily skipped by a reader impatient with these illuminating mathematical excursions.

More problematic is a torrent of proper names, both of people and geographical locations. For someone familiar with Dutch history and geography, these may pose no difficulty, but the account would have been rendered more widely accessible with a few strategically placed maps and a glossary of personal names. For instance, the first chapter, which is entitled 'Titan', ends with a paragraph concerning Huygens' discovery of the brightest satellite of Saturn, which he named Titan. Andriesse concludes by remarking that Titan is a fitting image for his subject, quoting a Latin couplet written by Huygens, translated as:

Let them remain as signs of my sagacity, and their names
That I write across the heavens be an echo to my fame.

Thereafter Andriesse often (and rather confusingly) refers to Huygens simply as Titan.

What makes the book an erratic read are the long sections from letters or diaries, filled with trivia (albeit colourful) and innuendo (regarding attractive ladies whom Huygens may or may not have taken to bed); these are interspersed with details of his mathematical or scientific achievements. My lingering impression is that the book is too uneven, and even perhaps too disturbing, to be recommended with enthusiasm.

On deeper reflection I realize that the book mirrors Huygens' own personality and psychology. Huygens was beset by painful episodes of melancholy when for many months he seems to have accomplished nothing, followed by great spurts of creative frenzy. The development of the wave theory of light, leading to the principle of the book's subtitle, occurred after a particularly devastating melancholic episode. Andriesse goes so far as to say: "It is thanks to this crisis that we have Christiaan's magnificent piece of work on light." All of this suggests to me that Huygens might well have suffered from