that software could not be created that would run a program as efficiently as the tedious machine-language programs, this eclectic group proved the doubters wrong. Programs in Fortran not only ran efficiently, but also changed the way people thought about software and made the computer much more widely accessible.

Lohr recounts the numerous computer languages created after Fortran, along with the intriguing personalities of their creators. He takes the reader on a fascinating tour through Cobol to Unix and C, through BASIC and Visual BASIC, and Algol to Pascal and C++. By this time, the stage is set for the personal computer and the rise of software as a separate business, and the end of the mainframe era when software was shipped as part of the computer. Although we have seen many advances that significantly increased the utility of the computer, software development continues to lag behind hardware and limits the performance and use of cutting-edge computing.

Lohr ends with the creation of the markup language HTML for the web and the philosophical battle being waged over open-source software such as Linux, for which the source code is freely available, and commercial software. It will be fascinating to see how the battle plays out over the next decade or so. ■

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In the eye of the beholder

It Must Be Beautiful: Great Equations of Modern Science
edited by Graham Farmelo
Granta: 2002. 224 pp. £20, $25

Ian Stewart

When Robert Recorde invented the equals sign he justified his choice of two parallel lines on the grounds that "no two thinges can be moare equalle". His inspired symbol, now indispensable in science and mathematics, forms an iconic decoration for the dustjacket of *It Must be Beautiful*.

The beauty of equations passes most of the human race by. But now we have a brilliantly readable book that absolutely revels in that beauty. Graham Farmelo has assembled a star-studded cast of authors and encouraged them to wax lyrical about their favourite equations. The book's main message is the one that Paul Dirac scrawled on a Moscow blackboard in 1955: "Physical laws should have mathematical beauty."

The essays are arranged in chronological order, based on the date of origin of the equation. Farmelo kicks off with the Planck–Einstein equation for the energy of a quantum of radiation, the discovery that started the quantum revolution. His essay is mainly historical, and the characters come to life before our eyes. Einstein turns up in several essays, probably because he set himself such high standards. We are told that the poet Paul Valéry kept a notebook to jot down his ideas, and asked Einstein if he did the same. "Oh, that's not necessary," said Albert. Then he added wistfully: "It's so seldom I have one." The ideas he did have, though, were stunning. It falls to Peter Galison to remind us of Einstein's most famous equation. It is, of course, $L = mV^2$. That's how Einstein first wrote it, if it seems unfamiliar.

Physics takes up about half of the book. Roger Penrose makes a valiant effort to explain general relativity, and tells us that the total energy of the gravitational waves radiated by Jupiter is about that of a 40-watt light bulb. Arthur Miller dishes the dirt on Schrödinger's equation — and his love life. Frank Wilczek revels in Dirac's relativistic equation for the electron, and Christine Sutton does a wonderful job on the Yang–Mills equations. The rest of the book is more varied: Igor Aleksander on Shannon's equations for information, Robert May on the logistic map of chaos theory, and John Maynard Smith on evolution. All of the essays are excellent, but some are more excellent than others.

Oliver Morton's contribution is rather offbeat: the Drake equation, used to estimate the prospects of finding intelligent aliens. As Jack Cohen and I point out in our forthcoming book *Evolving the Alien* (Ebury Press), the equation itself is open to serious criticism — as, even more so, is its extension in Peter Ward and Donald Brownlee's *Rare Earth* (Copernicus, 2000). But its history is fascinating. Even more fascinating is Aisling Irwin's account of the Molina–Rowland equations, which explain why chlorofluorocarbons destroy ozone, and predicted that they would. Those equations may just have saved the planet.

Finally, Steven Weinberg muses wisely on the staying power of a good equation, pointing out that all of the equations in the book are actually wrong — and are all the better for it. A comprehensible and insightful model beats an exact description any day.

It would have rounded off the discussion if at least one purely mathematical equation had been included — maybe Euler's $e^{i\pi} = -1$, or one of Ramanujan's partition formulas. The beauty of equations resides in their mathematical form and implications; applications relate to their importance as models of the real world. But the two are linked,

A Renaissance world view

The *Nuremberg Chronicle*, more correctly known as the *Weltchronik*, or *Chronicle of the World*, was an extraordinary Renaissance achievement, and one of the most important works ever published. It is an illustrated encyclopedia of the world as it was known in Germany near the end of the fifteenth century. Most of its knowledge is drawn from the Bible, but it also records contemporary events, including the falling of a meteorite on the Alsace, and some history of medicine. It includes maps of important cities, and a map of the world — just too early to include Columbus's new findings. Compiled by Hartmann Schedel in Nuremberg, the book was illustrated by renowned artists and engravers including Albrecht Dürer, who went on to become Germany's best-known Renaissance painter. Taschen has now published a luxurious fascimile of the massive chronicle (£40, $60, 60 euros), with extensive commentary in several languages.

which was Dirac's point. Many of the most beautiful equations of mathematics originated in questions posed by science. But some beautiful equations didn't, and that ought to be said, too. Let's hope there is a sequel. ■

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A milestone for a new millennium

The Human Genome
edited by Carina Dennis & Richard Gallagher
Palgrave: 2001. 156 pp. £19.99, $30

Daniel Cohen

The sequencing of the human genome was the last major goal to be set by leaders of science in the twentieth century. Its achievement was certainly as spectacular a triumph as the launching of the first spacecraft or landing on the Moon. It was also an amazing example of cooperation and competition between scientists, government funding agencies, charities, and public and privately funded projects. In a symbolic way it is a manifestation of the dramatic cultural changes that humanity undergoes at the turn of a new millennium.

Nature was an active supporter of the project to sequence the human genome, promoting ideas, lobbying for more funds and publishing outstanding achievements, including a completed draft sequence. So it is natural to see two senior editors of *Nature* compiling a book on this epochal achievement. The book is aimed at both non-specialists and students in the field, and presents the goals, history and consequences of obtaining the genome sequence. With a foreword by James Watson, the book describes early achievements in DNA structure and human genome mapping, followed by a detailed account of the dramatic course of events that led to the sequencing the human genome ahead of schedule.

The style is very clear and the authors present not only the facts, but also the spirit of this dramatic race. Although it is probably too early for a full understanding, the authors have tried to assess the future impact of human genome sequencing on biology, medicine and society. The book contains very good illustrations and historical photographs of key participants of the project. The original article reporting the sequence obtained by the public consortium, with schematic gene maps and accompanying papers, makes up more than half of the book. It will be a pleasure for any scientist to have this milestone book in their personal library. ■

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Science in culture

Knowing neurons

A dynamic installation highlighting the fluidity of brain function

Martin Kemp

"*The work is a homage to the beauty and sheer complexity of the structure and its steady development, its genetically-driven growth influenced by experience.*"

"*The complexity and beauty of its structure… reflects the developmental constraints that shaped its growth.*"

These two quotes are from writers extolling the wonder of the neuron, as disclosed by modern neurobiology. The first is from Andrew Carnie, one of the 'researching artists' featured in the exhibition "Head On. Art with the Brain in Mind" at the Science Museum in London (on view until 28 July 2002). The second is from Richard Wingate of the Medical Research Centre for Developmental Neurobiology, King's College London, in whose laboratory Carnie was introduced first-hand to "the distributed circuitry whose logic remains one of the greatest mysteries of biology" (Wingate again).

Their shared experience was the result of one of eight such collaborations set up by the curators of the exhibition — Caterina Albano, Ken Arnold and Marina Wallace — under the aegis of the Wellcome Trust. The other artists are Osi Audu, Annie Cattrel, Catherine Dowson, Letizia Galli, Claude Heath, Gerhard Lang and Tim O'Riley.

In building up his three-dimensional visualization of the brain, Carnie looked back to the pioneering work of Santiago Ramon y Cajal. Cajal used thin slices of tissue, impregnated with resin and stained by a method invented by Camillo Golgi, to construct an imaginative spatial picture of the cellular structure within the brain. Using Golgi stains, Cajal was able to infer the composition of different brain regions and even to suggest the direction of information flow. Cajal and Golgi were awarded Nobel prizes in 1906.

The modern resources available to Carnie, such as laser-scanning confocal microscopes and MRI scans, can be used to create compelling spatial arrays and to transcend the static pictures of morbid anatomy, capturing the three-dimensional dynamism of the living circuitry. Carnie was drawn into the amazing worlds of the proliferation, migration and connectivity of neurons in the developing mind, particularly as drifting memories are laid down.

What Carnie set out to capture in his installation, *Magic Forest* (above), was not an illustration of brain physiology but an evocation of the fluid flux that is the essence of neuronal transformation, as the growing cells extend their branches to communicate with companions near and far. Two projectors stand three metres apart on plinths at either end of a darkened space. They alternately project 160 slides on to three large gauze screens. As the images dissolve into one another, the forest grows and diminishes, comes and goes, builds and collapses, layer by layer, in an endless loop of generation and decay.

At these cutting edges of creative visualization, the tasks of the artist and the scientist both begin at the boundaries where knowledge runs thin. The artist gives vent to his awe through the magic of visual suggestion; the scientist through an insatiable urge to explain 'how'.

"It has been a breathtaking experience." The words are Carnie's, but they could have been said by any scientist grappling with what Wingate calls the "slices, fragments and snapshots" that "remain, for the time being, the basis of our understanding of neuroanatomy".

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