Designer genes and legal briefs

Remaking Eden: Cloning and Beyond in a Brave New World
by Lee M. Silver
Avon/Weidenfeld and Nicolson: 1998. Pp. 315. $25, £20

John Cairns

In the nineteenth century, most of what was going on in the sciences was accessible to the whole of the reading public. George Eliot, it is said, was engrossed in the proofs of Darwin's *Origin of Species* on the day it was published; and doctors in the United States had built their own X-ray machines for the treatment of breast cancer within a few months of reading about Röntgen's discovery of X-rays. During the past century, however, science has become so weighed down with facts that most of us can understand it only through the use of some kind of intermediary.

At the same time, science has become increasingly important. Political changes dominated the nineteenth century; science promises to dominate the twenty-first. Because democracy has proved to be, in the long run, the safest political system, it is very important that everyone, not just an intellectual élite, should have access to reliable guides to the science underlying what is happening to the human condition.

Nowhere is this more important than in the matter of genetic engineering, where opportunities for irreversible mischief seem almost limitless. So it is a great pleasure to report that Lee M. Silver's book about the genetic engineering of humans is very good indeed. He has first-hand knowledge of his subject and writes clearly and skilfully. His book covers the ways in which we are now able, or may soon be able, to decide the genetic constitution of our children. The description is in the form of a series of little family histories, some real, some imaginary. Each serves to introduce some particular technology and is accompanied by an account of the relevant sector of molecular biology or developmental genetics.

Some of the problems have already come to light. For example, what should be done with frozen embryos if both parents are killed in an accident? Is it right for a woman to decide to have a second child so that it can provide the marrow transplant that may save the life of a first child who is dying of leukaemia?

Other problems are just around the corner. Should a woman be allowed to bear a daughter who is a clone of herself (and, I might add, if the woman later dies, should her widower be allowed to marry the clone on the grounds that he is, in effect, remarrying his wife)?

Some of the case histories discussed by

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Nice body work: products of engineering as foreseen in the film *Brave New World*.

Silver promise to be as divisive as the issue of abortion. He seems particularly worried that genetic manipulation may eventually be able to offer general benefits, such as increased intelligence and resistance to disease. Because of the expense, these benefits will be available only to the rich, and he fears that, after many generations of manipulation, the human population may find itself divided into two distinct species (he calls them 'GeneRich' and 'Naturals') that cannot interbreed. Of course, the separation into rich and poor has been with us since the beginning of civilization, but has been partly relieved by a steady flow between the two groups owing to the fluctuation in people's fortunes. A division based on artificially enhanced intelligence might be far more destructive. (I understood that the British Labour Party, when it came to power after the Second World War, decided to leave untouched the so-called public schools because it felt that an oligarchy based on wealth was bound to be less entrenched than one created by extra education for the cleverest children.)

The book deserves to be widely read, not least because it gives such a lucid account of the science. But I am less worried than Silver about the genetic engineering of humans. Far more important, I think, is the danger if we come to rely exclusively on highly engineered crops, and the danger posed by new microorganisms that terrorists can now design using equipment as compact as the apparatus of the nineteenth-century physicist that could have been brought in by his butler, on a tray. Surely, if there is a forbidden apple in the new Eden, it is most likely to be found in the genetics of plants or microbes.

I hope that Silver will now look at these other fruits of genetic engineering. In some ways they are harder subjects because they do not concern simply the morality and legality of what can be done. But they are a more likely way for mankind to get into trouble than just by meddling with the genes of some of the richer members of the richer nations. □

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Spin doctors

Paul Dirac: The Man and his Work
edited by Peter Goddard
Cambridge University Press: 1998. Pp. 124. £12.95, $19.95

The Story of Spin
by Sin-itiro Tomonaga, translated by Takeshi Oka
University of Chicago Press: 1997. Pp. 258. $50, £39.95

Ian Aitchison

On the left, leaning elegantly backwards at an angle of 30 degrees to the vertical (but supported by solid stonework), head attentively inclined, is the slighter and older figure; on the right, vertically framing the space left by his listener's tilt, hands persuasively moulding the shape of the argument, is the handsome younger one. The old master and the young; the old world and the new; it is (as the caption says) "Dirac and Feynman discussing Physics".

The photograph, one of my favourite

images, is reproduced in Maurice Jacob's comprehensive lecture on antimatter, one of four given on 13 November 1995 to mark the dedication to Paul Dirac of a plaque in Westminster Abbey in London, and collected together in *Paul Dirac: The Man and his Work*, edited by Peter Goddard. The diamond-shaped plaque itself is also reproduced, opposite the first page of Stephen Hawking's Dirac memorial address, which introduces the volume.

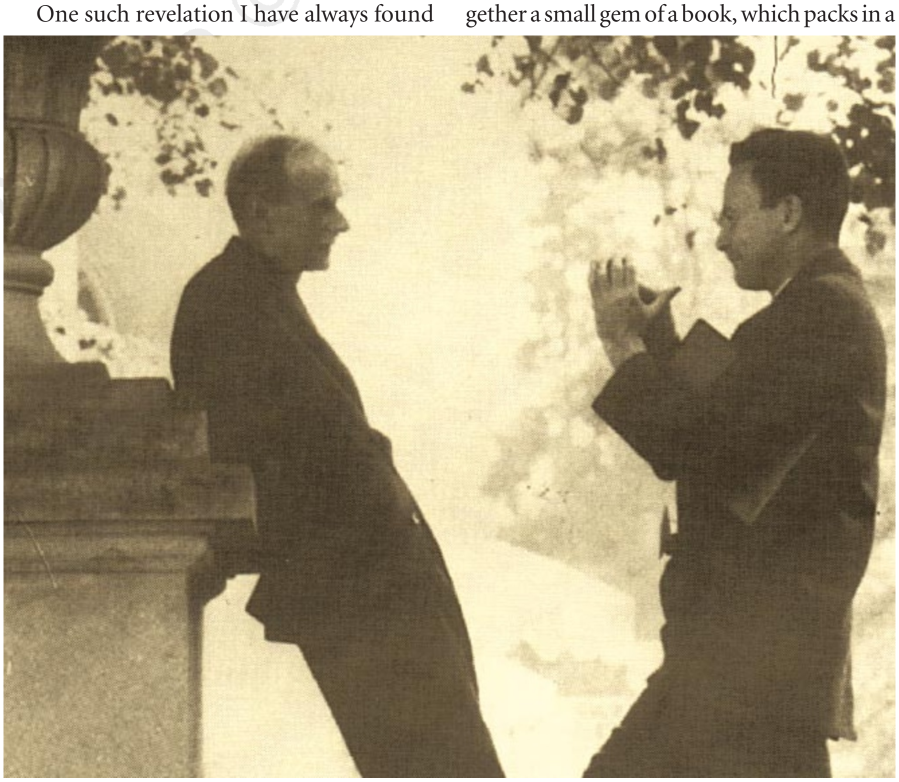
The most remarkable thing about the plaque is that the Dirac equation is on it, the first equation (a latter-day commandment?) to reach the sanctum where many of Britain's cultural and artistic heroes are commemorated. It was surely a brilliant idea to include the equation on the plaque, the execution being helped, no doubt, by the use of Feynman's more compact gamma-matrix notation in place of Dirac's original alphas.

It may be some time before the compression of knowledge will allow well-educated visitors to enjoy its significance, but the Dirac equation will surely always continue to fascinate theoretical physicists. Which of them has not had the secret dream of being able, like Dirac, to discover a true and permanent part of the mathematical structure of the world after only a few sentences of simple argument? Yet, as Abraham Pais reminds us in his scholarly and intimate contribution, Dirac's own 'darling' was not the equation of 1928, but his transformation theory of 1927, which is both the simplest and most general mathematical formulation of quantum theory. As Pais says, such self-revelations by Dirac were rare, but all the more precious.

One such revelation I have always found remarkable is quoted by David Olive in his lecture on monopoles. At the 1977 Enrico Fermi school in Varenna, Dirac confessed that the reason he had not, at a certain stage, pressed on with higher approximations (which would have tested his theory more severely) was that he "was afraid... the results might not come out right".

The collector of the more usual type of Dirac story will find many in the book. I much enjoyed one told by Jacob in which, after a lecture by Murray Gell-Mann on quarks, Dirac told Gell-Mann that he believed in quarks. "Wonderful," said Gell-Mann, overjoyed, "but what is your main reason?" "It is because they have spin," was Dirac's answer.

In arriving at his equation, which describes a relativistic particle of spin ½, Dirac was famously motivated by considerations of mathematical beauty which, in his hands, could be a powerful heuristic tool in the search for physical laws. The fourth lecture in Goddard's collection is by Sir Michael Atiyah, and is the most mathematical (and succinct) of the four. Atiyah reviews the role in mathematics of the differential operator introduced by Dirac in his equation, which is essentially a formal square root of the wave operator. He then discusses various aspects of the Atiyah–Singer index theorem and its significance for physics in quantum violations of classical symmetries through 'anomalies'. Both Olive and Atiyah end their lectures by referring to recent fruitful interconnections between mathematics and physics in the work of Simon Donaldson and of Nathan Seiberg and Edward Witten. This is altogether a small gem of a book, which packs in a great deal of information, anecdote and learning.



Past masters: Dirac (left) and Feynman.

The Story of Spin is a refreshing contrast, though there are many fascinating connections. For example, in the first book, Pais mentions a trip to Japan taken by Dirac and Werner Heisenberg in 1929. Sin-itiro Tomonaga, then 23 years old and recently graduated from Kyoto University, went to Tokyo to hear their lectures. He reproduces a photograph of the occasion, and writes: "Miraculously, I could more or less understand the content of the lectures, because fortunately I had already looked through papers related to these talks...[although] this required great labour."

Tomonaga went on to share the 1965 Nobel prize for physics with Feynman and Julian Schwinger for the development of quantum electrodynamics, a theory initiated by Dirac. Unusually, his book, first published in Japanese in 1974, five years before his death, is devoted almost entirely to the single topic of spin, that strange attribute of particles which Wolfgang Pauli in 1924 called a "classically indescribable two-valuedness" and which Dirac's equation, in a sense, explains. But it was an inspired idea to give a course of lectures on spin, and in the process provide a fresh and personal perspective on the development of quantum mechanics from about 1920 to 1940. After all, as the translator Takeshi Oka remarks: "The existence of spin, and the statistics associated with it, is the most subtle and ingenious design of nature — without it the whole universe would collapse." This is, perhaps, part of what Dirac meant in his reply to Gell-Mann.

The spin–statistics connection was first proved by Pauli in 1940, and Tomonaga describes the argument in the eighth of his twelve lectures. The first three describe prequantal analysis of atomic spectra, the emergence of Pauli's two-valuedness idea, the triumphs and tragedies of the 'self-rotating electron' model, and then Pauli's spin theory and the Dirac equation. Next come the story of how proton spin was determined in 1927 from the specific heat of molecular hydrogen, and Heisenberg's explanation of ferromagnetism in terms of an exchange interaction and the spin–statistics connection. The sixth lecture describes the origins of field quantization, and the seventh gives an elementary account of the behaviour of that "mysterious tribe by the name of spinor family", as Paul Ehrenfest called these quantities, which are neither vector nor tensor.

By the ninth lecture we have reached 1932 and the discovery of the neutron (and its spin), followed by the "pulling down... of the walls of the nuclear sanctuary, which had been thought to be impenetrable by quantum mechanics." The story reaches its climax in the tenth lecture, with Heisenberg's theory of nuclear forces and the concept of isospin, Enrico Fermi's theory of beta-decay, and Hideki Yukawa's wonderful paper of 1935 in which he introduced the idea of virtual quanta, proposed the existence of a heavy nuclear force quantum, and prefigured today's Standard Model of beta-decay.

Tomonaga's style is informal and often humorous. In the epilogue, he thinks of "an old sailor talking on and on about his youthful adventures" as he "spins a yarn". The story of those 20-odd years in physics has been told before, but never from quite this perspective. Thanks to Oka's translation, Tomonaga's lectures will now be read and enjoyed by the wide audience they deserve. □

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Colourful explanations

The island continent of Australia is known for its bizarre, colourful and often unique wildlife, from the marsupials and egg-laying mammals to the sea creatures of the Great Barrier Reef. Western Australia is particularly noted for its wildflowers, with more than 2,000 native species including the official state flower, the kangaroo paw (above). In *A Natural History of Australia* (Academic Press, $44.95), Tim M. Berra sets out to explain how the flora and fauna have been shaped by the isolation and aridity of the continent. The book is aimed at the interested visitor, incorporating a geography of Australia and useful information for the traveller.

Plant roots

The Origin and Early Diversification of Land Plants: A Cladistic Study
by Paul Kenrick and Peter R. Crane
Smithsonian Institution Press: 1997. Pp. 592. $55, £21.50

Sandy Knapp

The evolution and diversification of life has always held a great fascination for biologists. If we are to understand the patterns of relationship of life today, it is imperative that we have some understanding of those in the past; it puts our small branches in perspective. The extremes of innovation and diversification that have occurred throughout history tell compelling stories, but need to be put into clear systematic perspective to be analysed effectively.

For plants, the emergence of terrestrial forms was the start of a period of unparalleled diversification and innovation. The pivotal events leading to the origins and diversification of land plants are similar to those involved in the Cambrian 'explosion' that so influenced the diversification of the Metazoa. The metazoan fossils of the Burgess Shale endlessly fascinate both scientists and the general public, but the plant fossils of the Rhynie chert are just as fascinating from the evolutionary point of view.

The study of evolution depends on phylogeny: without hypotheses of the patterns of character distribution, and thus relationships between groups of organisms, no evolutionary hypotheses can really be constructed. The power and beauty of the approach of Paul Kenrick and Peter R. Crane to the analysis of land-plant relationships lies in their use of cladistic methodology. The focus on comparative morphology, and the testing of their own and other hypotheses of specific relationships, means that they truly achieve the objective set out in the first pages of the book: "to begin to synthesize the data that are currently available for resolving phylogenetic, and hence evolutionary, patterns among 'basal' groups of land plants."

This is not a book that tells a story based on an existing phylogeny; these are the real data, the characters that resolve the pattern, warts and all. It is tempting to think that evolution can be studied by simply plotting characters of interest on pre-existing phylogenies (usually constructed using molecular data), but Kenrick and Crane show how truly effective the alternative approach can be: that of an in-depth analysis of characters and their distribution using cladistic methodologies.

The book is constructed in a nesting set of detailed treatments of ever more detailed monophyletic groups. For example, the chapter on the relationships between embryophytes is followed by a chapter on the relationships among the polysporangiophytes, tracheophytes and euphyllophytes, all members of the preceding group. Each chapter is constructed similarly, making the characters and methodology comparable at each stage of the analysis. The choice of taxa used in each analysis is detailed, and all characters used in the analysis are described in detail and their coding justified. This is unusual in a book of this sort, and is a welcome innovation. Kenrick and Crane also analyse carefully the degree of applicability of each character and state how many taxa had missing data for each character used.

This may seem like unnecessary detail for a synthetic book of this kind, but it allows one to assess the authors' confidence in a character, rather than just taking their word for it. Characters with significant missing data — often those cellular details that are difficult to see in fossils — are also discussed in detail, and other potentially relevant characters not used in the analysis are considered as well. This honest and open approach, not often used because it reveals the limits of both the data and those analysing it, will surely stimulate palaeobotanists to re-examine fossils in museums around the world to redefine and refine the knowledge of these potentially useful characters.

The cladistic classification of the plant kingdom (Chlorobionta) is a model for how monophyly can be used as the defining principle for classification. A table of synapomorphy-based definitions of monophyletic higher taxa provides an extremely effective summary of the power of the cladistic approach. The in-depth discussion of developmental transformations in the context of taxic homology puts the characters used in Kenrick and Crane's analyses in perspective and allows them to set the stage for the next advances in the understanding of land-plant evolution.

This excellent and detailed book stands as a model for how to approach the study of evolution, and is an essential addition to the bookshelves of anyone interested in the scope and diversification of life. □

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