Powering the planet

From Space to Earth: The Story of Solar Electricity
by John Perlin
Aatec: 1999. 224 pp. $32, £22.50

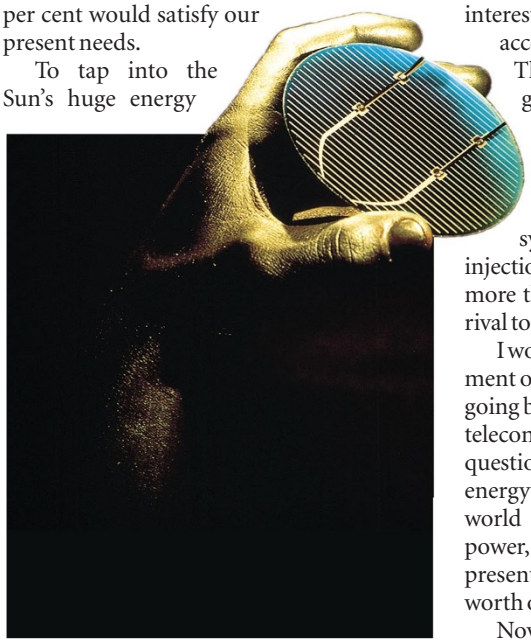
Michael Grätzel

Ever since the French scientist Henri Becquerel discovered the photoelectric effect in 1839, researchers and engineers have been infatuated with the idea of converting light into electric power. There is a magical aspect to solar cells that attracts a wide spectrum of people ranging from illiterate amateurs to highly trained professionals, from penniless entrepreneurs to wealthy sponsors. Their common dream is to collect the energy that is freely available from sunlight and turn it into the valuable and strategically important asset that is electric power.

The development of solar cells is also promoted by the increasing public awareness that the Earth's oil reserves will run out this century. As the planet's energy needs will at least double within the next 50 years, the stage is set for a major energy shortage unless renewable energy can cover the large deficit that fossil fuels can no longer furnish. Public concern has heightened recently as a result of the disastrous environmental pollution from oil spills and the frightening climatic consequences of global warming from the combustion of fossil fuels.

Fortunately, the supply of energy from the Sun to the Earth is gigantic — 3.2×10^{24} joules per year, or about 10,000 times more than mankind's current consumption. In other words, covering only 0.1 per cent of the Earth's surface with solar cells possessing an efficiency of 10 per cent would satisfy our present needs.

To tap into the Sun's huge energy reservoir remains, nevertheless, a major challenge for mankind. John Perlin's book gives a taste of the tremendous difficulties that early pioneers had to overcome in order to turn Charles Fritt's 1885 invention of a selenium-based solar module into today's booming photovoltaic business. Solar cells functioned very poorly for long after their discovery, with conversion yields of below one per cent. They remained a curiosity until 1954, when Calvin Fuller and Gerald Pearson from Bell Laboratories realized the first silicon-based p–n junction device, which achieved an efficiency of close to six per cent.



PHILIPPE PLAILLY/SPL

Light work: solar cells are becoming efficient enough to rival conventional solid-state cells.

Despite such an impressive advance, this would probably not have been exploited commercially without the advent of the space age. It was the need to power satellites that gave the breakthrough to solar cells. Only space applications were able to afford their very high price, that is, several hundred dollars per watt of electric power produced by the solar panels. When the price of solar cells dropped to $20 per watt they became competitive with primary batteries for remote-site terrestrial applications, mainly in the telecommunications field. Today the cost has come down to $5 per watt, opening up commercial opportunities for building integrated solar installations connected to the grid.

Starting with the space application, Perlin gives a vivid and fascinating historical account of the advances of photovoltaics on Earth. His book tells us the success story of the pioneers of solar cells, crediting them for their imagination and perseverance. One of the remarkable individuals described is Father Bernard Verspieren, who saved many lives by installing solar-driven water pumps in Mali. Presenting the history of the development of photovoltaic cells in such a personalized manner makes it a much more lively and interesting read than a mere technical account would have done.

The book focuses strongly on silicon; gallium arsenide cells, currently the most efficient solar-light-energy converters and widely used in space applications, are not mentioned. Nor are thin-film molecular photovoltaic systems such as the nanocrystalline-injection solar cell, which has an efficiency of more than 10 per cent, becoming a credible rival to conventional solid-state cells.

I would have liked a more extensive assessment of the future potential of photovoltaics, going beyond its use as a power source for the telecommunications industry. The crucial question is whether solar cells can supply energy for the planet on a major scale. The world currently needs 10,000 gigawatts of power, a staggering figure compared with the present yearly installations of 100 megawatts' worth of photovoltaic panels.

Novel concepts that do not rely on conventional p–n junctions may well be necessary to achieve the significant cost reduction required for large-scale applications of solar cells. The newly emerging field of molecular photovoltaics holds great promise in this respect. These systems operate like a plant's photosynthesis, mimicking a process that has worked well for the past 3.5 billion years, providing all the world's fossil energy reserves. The use of artificial photosynthesis for converting and storing solar energy provides exciting prospects for the new millennium. ■

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An evolutionary odyssey

The Human Career: Human Biological and Cultural Origins (second edition)
by Richard G. Klein
University of Chicago Press: 1999. 810 pp. $45, £31.50

Jean-Jacques Hublin

Four and a half million years ago, the first hominids were just another species of African ape competing for new ecological niches. Like all other species before them, the pre-humans followed the well-trodden path of biological adaptation. However, in the course of their evolution, humans would differentiate dramatically from any other beings by developing increasingly complex technologies. Culture finally played an overwhelming role in their adaptive success, making them menacing challengers for control of the entire biosphere. Most of the human odyssey is summed up in the following statement: more and more cultural adaptation, less and less biological adaptation, but some, nonetheless.

The notion of palaeoanthropology refers to the need to deal with both human palaeontology and palaeolithic archaeology in order to understand the extraordinary singularity of human evolution. This is the scope of *The Human Career,* but, surprisingly, of very few comparable publications. In its initial version, this book by Richard Klein was intended mainly for students. But after a decade of spectacular progress and controversies in this field, the book's format and contents have been completely revised, and it has been transformed from a textbook to a source-book. Its second edition stands out in the landscape of scientific publishing.

The Human Career describes one of the most spectacular changes to have occurred in our understanding of human evolution. The once-popular fresco showing a single file of marching hominids becoming ever more vertical, tall and hairless now appears to be a fiction. Humankind did not simply pass though successive stages, eventually leading

to the emergence of anatomically and behaviourally modern humans. For most of the past four million years, several species of hominids coexisted, sometimes in limited geographical areas. The eventual peopling of the planet with a single, homogeneous species of hominid is shown to be exceptional on the geological timescale. The phenomenon is especially noticeable with the first hominids, the australopithecines, for which eight species are now listed in the indexes. In the fierce controversies over the origin and relationships of these pre-humans, Klein is an outsider, developing his own views in a moderate style without becoming trapped in the usual pitfalls of either ignoring or trying to ridicule contradictory arguments.

A first 'out of Africa' movement followed the rise of a new model of hominid some 1.8 million years ago. *Homo ergaster*, a genuine human, was a tall, sweaty hunter adapted to open landscapes. This first movement resulted in the colonization of most of the warm and temperate zones of the Old World. *Homo erectus* developed in the Far East and Neanderthals in Europe. Eventually, one species, *Homo sapiens*, expanded to replace or outnumber its predecessors. The mechanism of the emergence of modern humans has been one of the most hotly debated issues in palaeoanthropology. Genetic and palaeontological evidence seems to support the African origin of all living populations. Yet questions remain over the path to modern humankind. Did certain archaic populations participate genetically in the development of the same living groups? How many 'out of Africa' events really occurred? What were the environmental and behavioural conditions of modern human expansion?

According to Klein, an 'out of Africa 2' movement started 50,000 years ago, spreading modern anatomy and behaviour throughout the planet. After a long period of very slow technical evolution, innovation and versatility suddenly became the engines of a genuine cultural revolution, while symbolic thought started to express itself. However, anatomically modern humans are known to have existed 100,000 years ago and did not develop any of these behaviours. Klein has his own answer to this puzzle. He favours the view that a neurological change occurred, rather than that purely linguistic, sociological and technical developments precipitated the revolution. This theory is hardly testable on the fossil record, and is where Klein will probably find most of his critics.

If you could have only one book that deals with human evolution, this is definitely the one to choose. In any event, the author has skilfully included all the others in it. If you are an aficionado, you will not want to miss this reference book describing the state of the art in a rapidly evolving field. ■

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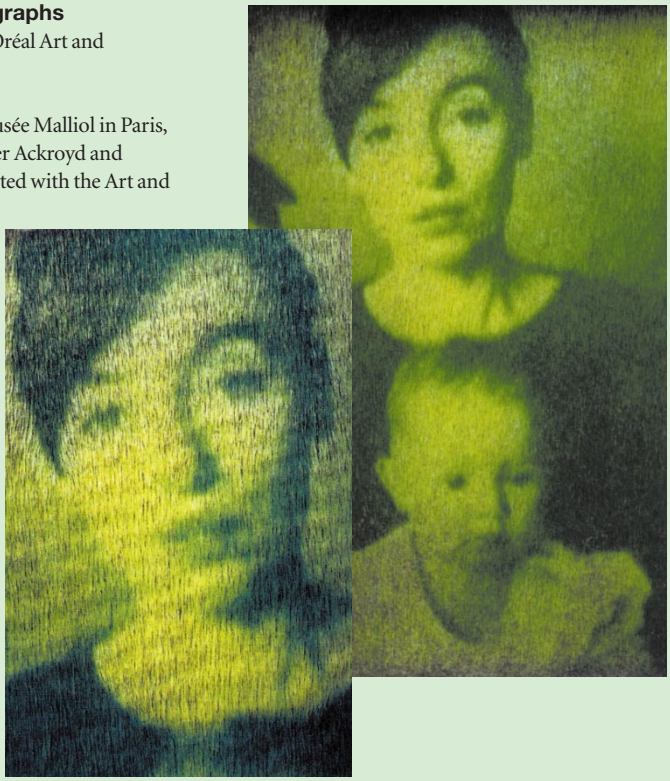
Science in culture

Photo-grass photographs

British artists win the L'Oréal Art and Science of Color Prize

Martin Kemp

On 25 January, at the Musée Malliol in Paris, the British artists Heather Ackroyd and Dan Harvey were presented with the Art and Science of Color Prize, awarded by the L'Oréal Art and Science Foundation. The prize was established in 1997 by the Tokyo-based foundation, the brainchild of Tetsuzo Kawamoto, for Japanese artists and scientists. It is intended to promote a creative dialogue between art, science and colour. This is its first international year, involving a multinational jury, including myself. The winners, Ackroyd and Harvey, use grass as a novel surface for producing photographic images.



Ackroyd and Harvey's *Mother and child*, created by grass photosynthesis.

Anyone who has seen the effect made by something lying on a grass lawn for a few days will have noticed the yellowish imprint when it is lifted away. The pale silhouette may be considered as a kind of photographic negative, fading from view when sunlight restores the yellowed grass to its former greenness. Using the photosensitive property of grass, Ackroyd and Harvey have collaborated with scientists at the Institute of Grassland and Environmental Research (IGER), at Aberystwyth in Wales, to perfect the production of fully legible, 'living' photographs on a germinating lawn.

Their positive photographic images are formed by the projection of a black-and-white negative onto the surface of the growing grass. Such is the sensitivity of each germinating blade of grass that it produces a chlorophyll concentration that corresponds directly to the quantity of light available to it. Leaves of varied colour, from a rich, dark green to a sickly pale yellow, combine to form tonal images of a subtly elusive kind. They strongly recall the soft beauty of the callotypes made by William Henry Fox-Talbot during the years immediately following the first announcement to the public of the rival French and British photographic processes in 1839.

The biological researchers with whom Ackroyd and Harvey worked at IGER during 1997–98, as a result of a Wellcome 'Sciart' award, are developing techniques for controlling the enzyme that degrades chlorophyll as a leaf dies. They have devised ways of modulating the expression of the gene responsible for the enzyme that causes the senescence of the green leaves. The scientists' newly engineered 'staygreens', which resist yellowing senescence, possess obvious potential for increasing the longevity of the artists' evanescent photographs. On their own behalf, Ackroyd and Harvey have placed particular demands on their unconventional medium in order to achieve minute gradations in green tonality. Their interests have been served by IGER's use of advanced visual analysis techniques, in particular the high-resolution imaging technique of hyperspectral analysis.

Ackroyd and Harvey's beguiling results, which revive the strange visual magic of early photographic images from more than 150 years ago, are underpinned by today's most advanced plant genetics and optical precision. Their grass-works testify to the ceaseless wonder of living nature in all its responsive subtlety, and to the more creative potential of human intervention in nature's supersensitive systems. Not least, it is a relief to find genetic engineering featuring in a story that does not involve scares — whether well- or ill-founded. ■

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