claimed that economic predictions are in principle inconsistent, because they cause agents to act in a different way from that predicted. His favourite example was the fictional detective Sherlock Holmes being pursued by the murderous Moriarty and having to decide where to leave a train, with Moriarty anticipating this, in a vicious circle of mutual outguessing. Morgenstern, the director of a forecasting agency in Austria, saw in this infinite regress ("He thinks that I think that he thinks…") a basic obstacle to forecasting the decisions of interacting individuals, no less fundamental than the uncertainty principle or the incompleteness theorem. Only later did he realize that von Neumann's 'maximin' solution, yielding the highest guaranteed payoff, offered a way out: mixed strategies (such as 'leave at Dover with probability of two-thirds') can be optimal, even if an adversary manages to guess them.

Although Morgenstern's love affair with mathematics was purely one-sided, he was closely acquainted with some of Vienna's best mathematicians, including the geometer Karl Menger, who co-discovered dimension theory, and the logician Kurt Gödel. Menger was so distressed by the political turmoil of the time that in autumn 1934 he withdrew to a mountain resort, where he wrote an odd little booklet on mathematical ethics, based on the 'tolerance principle'. Just as there is not one geometry but many (euclidean, hyperbolic and elliptic, for example), so there is not one system of moral norms but many, from which individuals make their own choice. Menger then studied how groups of adherents to different norms interrelated.

In 1938, Morgenstern was prevented from returning to Austria from the United States by the Nazis, who had blacklisted him. During his exile in Princeton, he sought to extend Menger's ideas in a paper on "Maxims of behavior", and to analyse societies of agents whose decisions impinge on each other. This was when von Neumann, who had not worked on game theory for ten years, stepped in, and eventually suggested that they write the paper together, for the benefit of economists. "Here was my gift from heaven," wrote Morgenstern. Their manuscript started growing relentlessly, becoming first a two-part paper, then a small pamphlet that Princeton University Press agreed to publish, and then the authors "completely forgot about any restriction to 100 pages".

The final product is not for the faint-hearted, and few will have had the stamina to work through its pages crammed with footnotes and formulae. But by its mere existence, the heavy tome marked a turning point in economics, challenging it to become a mathematical discipline at last. ■

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JEFFREY L. ROTMAN/CORBIS

Into the depths: the body can muster an extraordinary range of defences against extreme conditions.

Life on the edge

The Biology of Human Survival: Life and Death in Extreme Environments
by Claude A. Piantadosi
Oxford University Press: 2003. 280 pp. £24.95, $35

Mike Stroud

Stories of human achievements and survival against the odds have always been fascinating. Whether in the context of simply living in the world's harshest environments, mounting expeditions to its hottest, coldest, highest or deepest places, or coping with the aftermath of disaster, everybody wonders at just how the body copes. Answers lie in the study of environmental physiology, the responses and adaptations that can take men and women to extremes.

The Biology of Human Survival is an extraordinary environmental physiology text. The topics covered range far beyond biology to include the physics and function of artificial aids that allow humans to cope with extremely hostile environments. But engineering approaches are not just used to describe life-supporting technologies — the author also uses them to explain biological concepts. This approach helped me to understand some concepts that I had previously struggled with. Occasionally, however, the opposite applies.

The book begins by describing the limits to the range of environments that can support human life, along with the principles of survival, adaptation and life-support systems. The historical background to environmental physiology is fascinating, but as the book moves on to adaptation (physiological changes in response to environmental stress) and maladaption (adverse changes resulting from adaptation), some topics were unclear and others were made unnecessarily complex. For example, the author stresses the importance of discriminating between technical definitions, such as adaptation, acclimatization, acclimation, accommodation and habituation, but then, I feel, blurs the boundaries. He has also focused particularly on maladaption and cross-acclimation (adaptive changes to one type of environmental stress that prove beneficial during exposure to stress from a different type of environment), perhaps ascribing more importance to these processes than they deserve. Indeed, he suggests that adverse effects of cross-acclimation between cold and hypoxic responses contribute to the difficulty of climbing Mount Everest in winter. In reality, this must be insignificant compared to winter's cold, storms and jet-stream winds.

But back to the book's strengths. Several chapters cover adaptation to heat and cold in detail. There are lengthy descriptions of human responses and adaptation to icy environments, but our physiological responses to heat (which are far more effective than those to cold) are not covered in such depth. This book is not, then, a definitive work on environmental physiology. But viewed as a collection of thought-provoking pieces about this field it becomes a tour de force. This is especially true when the author strays from his title, covering not just engineering and biology, but also life that is far from

Science in culture

Great, not gruesome

Pat York's photographs of dissected humans represent a fine body of work.

Martin Kemp

The notable eighteenth-century German anatomist Bernhard Siegfried Albinus demonstrated that skin colour — the characteristic we use most readily to judge someone's ethnic origins — was literally a superficial matter. He also disclosed, not least through the stylish illustrations he commissioned from Jan Wandelaar for his grand *Tabulae sceleti et musculorum corporos humani* in 1747, that the inner topography of the dissected body was no less wondrous and beautiful than its exterior. How could it be otherwise, as anatomists had long claimed that the human frame was God's greatest achievement as divine engineer?

These themes are reincarnated in Pat York's remarkable photographs of dissections performed by the Los Angeles anatomist Marc Pick. Over the course of seven years, York has been granted regular access to the products of Pick's manual, intellectual and creative skills. She describes what she has witnessed as "one of the most awesome experiences of my life" and adds: "I feel an unwonted affinity for these still, complex bodies."

On the face of it, such ostensibly gruesome subjects could hardly represent a sharper contrast to the images that first gained her fame, namely her portraits of celebrities, mostly from the Hollywood world of film. Yet when we look back on how she has presented the famous, and also at her suites of photographs of workers in the nude and of vibrant people over 75 years old, we can see that she has always been interested in what lies below the surface. The body, the face and the eyes have always acted for her as a "window to the soul".

Now, in a work such as *Universal Self-Portrait*, shown here, she is re-examining our relationship with our own bodies. Superbly executed, direct and starkly compelling, the image challenges us to look again at what we all have inside ourselves but prefer not to confront visually or emotionally. We find it more comfortable to live our lives on the surface of who we are defined as being. In her image, the brain, folded like some complex product of vast geological torsions, is the seat of much of what makes us individual, yet she emphasizes that "the body, when the skin is peeled away, has no distinctions of colour, race or religion".

PAT YORK

The strange wonder of our inner selves draws York into the biggest issues that have confronted humanity over the ages. "We all have souls, we all have hopes and dreams, both fulfilled and otherwise, and we all have loves and passions. Where are those souls now? Have they been reincarnated? Are they in heaven? Is there just a void?" She continues: "We all share this miraculous, complex interior — far more complicated than any technological advances we have made in our society. I am constantly mesmerized at the complexity of the human experience, and baffled by the existence of hatred and violence. If only in life we could see our similarities — differences do not apply. It seems ironic that the only thing we are sure about in life is that we shall die, the one fact we all seem to wish to escape. *Universal Self-Portrait* is all of us."

Albinus subscribed to the traditional notion that the justification for dissection was to "know thyself". Pat York's work stands centrally in this tradition in a way that the flashy, opportunistic and exploitative displays of Gunther von Hagens do not. Von Hagens poses beautifully dissected bodies in irrelevantly rhetorical poses. The great anatomists knew that presentation, pose, significance and communication should be totally integrated if they were to do their momentous job with the highest levels of integrity. York's pictures of the dissected body similarly allow no compromise in allying form and meaning.

York's photographs went on display this week at the Galerie Gmurzynska in Cologne, Germany, where they can be seen until 23 October.

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human. The piece on the physiology of the camel in the section on salt and water is masterly, and there are fascinating descriptions of the interaction between primitive life and Earth's early atmosphere. There is also a beautifully worked analysis of why you should never drink sea water.

The chapter on nutrition and survival, although generally excellent, does perpetuate some rather outdated views. For example, it states that the main difference between the forms of malnutrition known as marasmus and kwashiorkor is in the level of protein intake; elsewhere in the book, the author mentions the more current idea that kwashiorkor and its accompanying oedema are more a product of free-radical membrane damage than low protein ingestion. There is also misleading information about the subsequent reintroduction of normal nutrition (refeeding), and there are some rather simplistic views on vitamin deficiency. These include the idea that the main problem with vitamin A depletion is ocular, whereas we now know that vitamin A deficiency also impairs responses to infections of the gut and respiratory tract, leading to deaths in people who have very little or no eye damage.

Biology and engineering are mixed even more freely in the second half of the book than in the first. Descriptions of the technical engineering solutions to the high pressures of the deep sea and low pressures of the high mountains are balanced excellently with descriptions of pressure physiology and the illnesses that can stem from pressure change. Just as in the earlier part of the book, in which problems caused by the cold are illustrated by compelling tales including those of Scott of the Antarctic and the *Titanic*, the author uses famous disasters to bring the issues in this section to life. The sinking of the Russian submarine *Kursk* is used to great effect.

Towards the end of the book there is a surprising but topical diversion into survival in the face of nuclear, biological and chemical weapons of mass destruction. This is a rather depressing digression, but it is both interesting and relevant.

The book ends with a section lifting us away from Earth's limitations to describe the exciting physiology and engineering of high-performance aircraft and space flight. The final chapter even speculates on the requirements for and limitations to future human colonization of other planets, and so ends on a positive note, as will I. There is no doubt

that this book will be enjoyed widely and will be much appreciated by both specialists and scientifically thoughtful lay readers. ■

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Uncovering chromosomes

The Man Who Invented the Chromosome: A Life of Cyril Darlington
by Oren Solomon Harman
Harvard University Press: 2004. 342 pp. $49.95, £32.95, €46.10

Rena Selya

JOHN INNES ARCHIVES

Look at it my way: the results of Darlington's unorthodox methods eventually convinced his critics.

Cyril Dean Darlington was responsible for our understanding of the behaviour of chromosomes during mitosis and meiosis. Working with plants at the John Innes Horticultural Institution in London in the 1920s, he displayed a keen eye for microscopy, and spent much of his time exploring the structures of the cell. His scientific insights, however, were more often the result of theoretical reasoning than careful empirical observation. His 1932 masterpiece, *Recent Advances in Cytology*, earned him both great praise and harsh criticism because of his unorthodox methods.

As Oren Solomon Harman shows in *The Man Who Invented the Chromosome*, Darlington's controversial cytological research clarified many basic biological issues and provided essential evidence for the evolutionary synthesis of the 1940s. He 'invented' the chromosome by describing its behaviour in a way that made genetic and evolutionary sense. His description of the way chromosomes line up with their homologous copies before cell division settled a long-running debate among cytologists over whether chromosomes pair up end to end or next to each other, and accounted for the phenomenon of crossing over. His contributions to biology were significant, yet he has been overlooked in the history of the life sciences.

One of the book's strengths is Harman's deft description of the confusion that reigned in the biological community in the first half of the twentieth century. He shows how well-educated, talented researchers could draw opposing biological conclusions from experimental data because of their conflicting disciplinary affiliations and generational perspectives. When Darlington began his work at the John Innes, under William Bateson, he stumbled into a community in epistemological upheaval. Despite his position as one of the founders of modern genetics, Bateson resisted the chromosome theory of inheritance because he felt there were too many experimental exceptions for it to explain mendelian inheritance. Young US geneticists were willing to extrapolate from data from a model organism, whereas cytologists spent years accumulating evidence from a range of plant and animal species before drawing general biological conclusions. Harman gives the reader a sense of Darlington's growing confidence as he made bold claims that were eventually accepted by biologists of all disciplines.

A strong commitment to an evolutionary perspective led Darlington to some unpopular conclusions, which he published in books and articles aimed at a wide audience. Convinced that biological principles, especially genetics, dictate human values, he espoused strong eugenic programmes and argued for the biological existence of race, especially after UNESCO published its statements on race in the early 1950s. Darlington studied human history through the lens of evolutionary pressure, concluding that genetic and environmental diversity should be maintained to ensure the survival of the human race. Although his ideas were unpopular so soon after the Second World War, he felt that the time had come for science to determine morality: religion and politics should be replaced by evolutionary logic for individuals, countries and humanity.

The influence of science on society was unidirectional, however. Darlington firmly believed that political considerations should never influence science, whether under liberal or totalitarian governments. He was one of the first scientists outside the Soviet Union to recognize the danger in Trofim Lysenko's scientific and political positions. Despite the fact that some of Darlington's work on cytoplasmic inheritance could have supported a lamarckian view of heredity, he criticized Lysenko's science while other biologists played down its influence. He took no pleasure in accurately predicting the terrible fate of Soviet geneticists, and he chastised colleagues who were loyal to the Communist party.

Darlington was a lifelong diarist, and Harman makes fine use of the red bound notebooks that now reside in the Bodleian Library in Oxford. He attributes Darlington's scientific success, after a lonely and academically undistinguished childhood, to a combination of intelligence, arrogance and the desire to please a demanding, emotionally distant father. Harman chronicles Darlington's tumultuous personal life (he had three wives), and incorporates the recollections of two of his children. He describes Darlington's thoughts and feelings in a novelistic manner, so the scientist comes across as a complex, if not altogether likeable, person.

The prose is occasionally melodramatic: "It was as if the chromosomes themselves, at the other end of the ocular lens, could feel it: Darlington was hungry." Still, the style conveys Darlington's human side well. Harman does not fall into the trap of tediously chronicling the life of his subject, but rather presents Darlington's scientific research and popular writings as the expression of paradoxical personal and intellectual themes.

Because of his controversial views and brusque personality, Darlington faded from the public eye before his death in 1981. But the spectres of genetic determinism and political interference in science remain with us, and Harman provides a cautionary tale for those who seek to tie our humanity too closely to what is found in our chromosomes. ■

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