generous to critics. The distinguished achievements in the history of ideas will be acclaimed, although the story of the self-destruction of a once-respected, learned discipline is saddening. □

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What did you do in the [cold] war, Daddy?

Biohazard
by Ken Alibek
Random House: 1999. 319 pp. $24.95, £17.99

Malcolm R. Dando

In his well-known history, *The Greatest Benefit to Mankind: A Medical History of Humanity from Antiquity to the Present* (HarperCollins), Roy Porter argued: "... the latter part of the nineteenth century brought one of medicines's few true revolutions: *bacteriology* [emphasis added]. Seemingly resolving age-old controversies over pathogenesis, a new and immensely powerful aetiological doctrine rapidly established itself ...". Porter went on to point out that, very unusually for medicine, this revolution brought dramatic and rapid benefits to the human population in new preventative measures and remedies. Unfortunately, the demonstration — by scientists of the standing of Louis Pasteur and Robert Koch — that specific diseases were caused by specific microorganisms, also raised the possibility that the new knowledge might be misused in offensive biological-warfare programmes. We know now that, during the First World War, both sides attempted to use biological weapons to sabotage the other side's valuable animal stocks.

Subsequently, during the middle of the twentieth century, other advances in biology and medicine — such as in aerobiology and production microbiology — were used in major offensive biological-warfare programmes by countries such as the United Kingdom and United States. For some years it appeared that such misuse of science had been halted by agreement of the Biological and Toxin Weapons Convention (BTWC) in the early 1970s. But the convention lacked any effective verification conditions, and it has recently become clear that the former Soviet Union embarked on a vast expansion of its biological-weapons programme at the very time the convention was agreed.

A proper description of the full extent of this modern programme is not available in the public domain. From a variety of sources, however, we know some of its characteristics. First, we know that it was carried out on a massive scale, with numerous institutes and many thousands of people involved. Second, it involved the large-scale creation of weapons involving a range of agents, and so implied a willingness to use biological weapons in major military operations. Finally, it is clear that recent advances in genetic engineering were being used — for example to increase the antibiotic resistance of plague.

Ken Alibek was one of the leading scientists and organizers of this offensive biological-weapons programme and, through a series of interviews on television and in newspapers and magazines, he has been a principal source of public knowledge about what was done. Alibek's book, *Biohazard*, ghostwritten by Stephen Handelman, gives a readable account of what can reasonably be called a 'chilling true story' in the form of an autobiography.

I feel strongly that this book should be compulsory reading for everyone involved in the dramatic biotechnology/genomics revolution today. Many other scientific advances have been applied in new weapons systems, and we will be fortunate indeed if modern biology is not misused in the same way.

Although Alibek's account may be fallible in parts, enough has been confirmed by other sources for the whole to be taken very seriously. Different readers will be struck by different parts of this story. For me, the account of project 'Bonfire' was particularly alarming. Alibek describes being in a long, boring review meeting in 1989. One of the last speakers was due to report on this project, which was a long-running attempt to genetically engineer a human pathogen to produce an additional toxin or bioregulator. Alibek recounts: "The test was a success. A single genetically engineered agent had produced symptoms of two different diseases, one of which could not be traced. The room was absolutely silent. We all recognized the implications ... A new class of weapons had been found ..."

He goes on to describe how such new weaponry might be used to damage heart function or to target the nervous system and behaviour. Today's neuroscientists, striving to find means of helping those afflicted by mental problems, might also be concerned by the related 'Flute' programme, which was devoted to developing psychotropic agents to induce mood and behavioural changes in people for malign purposes.

Nevertheless, Alibek comes over in the book as a thoughtful and decent man. We could all perhaps learn from his experience. In his final paragraph he states: "... I cannot unmake the weapons I manufactured or undo the research I authorized as scientific chief of the Soviet Union's biological weapons programme ..."

He continues: "... but every day I do what I can to mitigate their effects. The realization that even today, in Iraq or China, another father of three may be sitting down at a conference table to plot the murder of millions of people is what spurs me on ..."

We should all ask ourselves whether we have done enough to help secure the agreement of the BTWC Verification Protocol now being negotiated in Geneva, for this is surely the best way available to us of preventing such misuse of biology and medicine. □

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Neural networks beyond Freud

The Mind Within the Net
by Manfred Spitzer
MIT Press: 1999. 359 pp. $27.50, £19.50

Terrence J. Sejnowski

Sigmund Freud was a pioneer in a field that today is called neural networks. Before turning to the 'talking cure', he sought explanations for normal as well as disordered thought processes in the flow of 'nervous energy' through networks of neurons, based on what was known about the neurophysiology and anatomy of the brain at the end of the nineteenth century. From these early speculative ideas came such concepts as repression and sublimation which would become the foundation of psychoanalysis. In *The Mind Within the Net*, psychiatrist Manfred Spitzer takes us back to these roots and asks whether recent advances in cognitive neuroscience and neural-network models provide a firmer foundation for explaining the mysteries of human experience.

Many of the important technical breakthroughs that fuelled the neural-network revolution that began in the 1980s were made by psychologists, as heralded in the two volumes on *Parallel Distributed Processing*, edited by David Rumelhart and James McClelland (MIT Press, 1986). A new mathematical foundation was developed for explaining human cognition based on models with continuous variables and dynamical systems rather than computer programs based on logic and symbol processing. Spitzer does not cover these latest developments, but has written a highly readable introduction to 'traditional' neural-network models.

Thinking about how populations of neurons encode the sensory world and motor coordination, and how they acquired these properties, is not easy. Computer simulations of relatively simple neural-network models have revealed their powerful ability to solve complex problems, such as the recognition of facial expressions. The same networks that were built to mimic normal human behaviour can also be used to explore the inexplicable breakdown patterns that occur when brains are damaged. *The Mind Within the Net* excels at exploring a wide range of clinical problems, including phantom limbs, autism and schizophrenia.

FROM *VISION: 50 YEARS OF BRITISH CREATIVITY* (THAMES & HUDSON)

Wiring up: neural-network models have thrown light on how we perceive and experience our world.

To the extent that the models can be related to brain systems, they can be tested and, eventually, the chasm that once separated the mind and the brain can be bridged.

One of the most surprising and puzzling recent discoveries in brain science has been the degree to which the cerebral cortex, the most highly evolved part of the human brain, remains malleable. The surface of the body is mapped onto the surface of the cortex in such a way that nearby points on the body map onto nearby neurons in the cortex. When a sensory nerve that innervates the fingers of a monkey is cut, the map reorganizes and the cortical area once dedicated to that patch of the body surface is, over time, reassigned to neighbouring body surfaces. This process involves both cortical and subcortical mechanisms for neural plasticity. Conversely, when a monkey is asked to use its fingers repeatedly over a long period, the area devoted to those fingers enlarges. Something similar happens in the somatosensory cortex of human Braille readers.

Neural-network models of cortical maps with Hebbian synaptic plasticity on the sensory inputs can reproduce the changes that occur during loss of neuronal input. Shortly after limb amputation in humans, vivid phantom sensations can occur, often accompanied by intractable pain that is referred to the missing limb. Curiously, reports of phantom limbs are rare following spinal injury leading to paraplegia. Why should these two ways of cutting off neuronal input to the cortex have such different perceptual consequences?

One possibility, explored by Spitzer in a cortical model, assumes that there is noise in the stump of the severed nerve. In the model, the noise excites cortical neurons and leads to cortical reorganization but, in the case of spinal injury where it is assumed that such noise is absent or reduced, the reorganization of the map in the model is attenuated. The advantage of the model is that plausible hypotheses can be generated and explored in a system whose complexity escapes direct reasoning.

Reading this book was like visiting an old friend after a long absence. The friend is ageing gracefully but has taken up new hobbies. Since these simple neural-network models were introduced we have learned much more about the brain, and a new generation of neural-network models has been explored, based on the detailed biophysical properties of neurons. Despite this greater sophistication, many of the concepts that emerged from the first generation of neural-network models are still applicable, such as attractor states and population codes. One major difference is a richer dynamic by virtue of the intrinsic properties of the neurons. With much faster computers it has also been possible to simulate more neurons and to test how the dynamical states scale with the size of the network.

Perhaps the most puzzling property that these new network models exhibit, mimicking the brain, is spontaneously active oscillations. New concepts are needed to explain the complex mixtures of rhythms that occur in these networks and to characterize their computational power. Perhaps ten years from now in a second edition Spitzer or his students will draw out the consequences of these new models for psychology and psychiatry in an equally clear and effective way.

The last chapter contains a brief "User's manual for your brain". Just as cardiologists can provide advice on diet and exercise to enhance your physical well-being, Spitzer provides a mental diet and exercise that may enhance brain development in children and maintain a sharp mental edge in adults. It should be possible to expand this user's manual as further discoveries are made about the brain and integrated into a clearer picture of how brains are influenced by the world.

Freud provided a language for organizing human experience that lasted nearly 100 years. A new language of the mind is now emerging from cognitive neuroscience and computer models that may have far-reaching consequences for how we see ourselves. □

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The first three billion years

Cradle of Life: The Discovery of Earth's Earliest Fossils
by J. William Schopf
Princeton University Press: 1999. 367 pp. $29.95, £17.95

Stefan Bengtson

Of all the fossils on Earth, some have to be the earliest. So what's the big deal, except for an entry in *The Guinness Book of Records*? Quite a big deal, in fact. The Phanerozoic — the 'time of visible [animal] life' of the past 550 million years — is now known to have been preceded by three billion years or more of Precambrian life, almost exclusively microbial. It seems that life appeared as soon as conditions at all permitted it. Life may well be (to use Christian de Duve's words) a cosmic imperative.

Bill Schopf has been a prime mover on this frontier, in his quest to find microfossils by slicing up uncountable chunks of the Earth's older crust and in his messianic efforts to bring together scientists of all creeds and talents to ask: 'What does it all mean?' His persistent questioning, arguing, pleading, shouting, bullying, persuading, fund-raising, entertaining, writing and editing have probably promoted and inspired more interdisciplinary work on the history of life than any other factor.

In the well-written *Cradle of Life*, Schopf tells his story of how Earth's early microbial biosphere was discovered. He ranges from biochemistry to natural history, science history and personal anecdotes, and although the path can be tortuous, it is not too convoluted. The many diagrams, however, usually lack information about data sources; this is particularly troublesome, as it is apparent that some plots are based on idealized data.

Schopf's treatment of the earlier players in the field is balanced and entertaining, but currently active players hardly get a mention. One could argue with some of the judge-