Today, no major economy is without the protection of an independent nuclear arsenal or a nuclear umbrella; and disarmament seems a dream, like nirvana. ■

Brahma Chellaney is at the Centre for Policy Research, Dharma Marg, Chanakyapuri, New Delhi 110021, India.

Counting on our brains

The Mathematical Brain
by Brian Butterworth
Macmillan: 1999. 480 pp. £20

Stanislas Dehaene

"One, two three, four. My mathematics finishes here." Those are the words of Signora Gaddi, an alert, 59-year-old Italian woman whose puzzling impairment has helped neuroscientists understand how the brain does arithmetic. Signora Gaddi suffered a stroke that damaged the left parietal lobe of her brain. Since then, she has become largely hopeless with arithmetic. She cannot read, write, compare or calculate with any numbers other than one, two, three and four. Even with numbers below four, she is definitely not performing normally. For instance, when shown two wooden blocks, she has to laboriously count on her fingers in order to establish their numerosity. Because Signora Gaddi performs normally on many other tests that do not involve numbers, her affliction can be described as a selective loss of arithmetic.

The detailed study of Signora Gaddi is just one of many fascinating pieces of evidence gathered by Brian Butterworth in his effort to illuminate the relations between brain, mind and mathematics in his book *The Mathematical Brain.* The title itself is something of a misnomer, for one would search this volume in vain for investigations of the cognitive bases of higher mathematics, or even of simple geometry, algebra or topology. The book focuses on a single mathematical object, but one that is rightly seen by Butterworth as a fundamental cornerstone of the mathematical edifice: the concept of number.

Butterworth's central hypothesis is that our brain is "born to count". Our genes contain instructions that specify how to build a number module, a set of neural circuits specialized for processing numbers. Those circuits, which are associated in part with the left inferior parietal lobe, make us sensitive to numerosities in our environment and allow us to understand and to manipulate numbers mentally. Loss of those circuits, as in Signora Gaddi's case, results in a selective inability to grasp the meaning of numbers. The number module is not unique to humans: behavioural experiments reveal that many animals can also attend to numerosity. What makes the human numerical ability unique, however, is that it can be extended through the invention and spreading of cultural tools, such as number symbols and arithmetic algorithms.

In recent years, the cognitive neuroscience of numeracy, or 'numerical cognition', has emerged as an important area where the interaction between brain architecture and human culture can be studied empirically. The hypothesis of a modular architecture underlying number processing has been fruitful in many areas of research, from developmental psychology to brain imaging, animal behaviour or behavioural genetics. Several previous reviews of these findings are available, some aimed at specialists (for example, *The Nature and Origins of Mathematical Skills* by J. I. D. Campbell; Elsevier, 1992), others at a wider audience (for example, *The Number Sense* by S. Dehaene; Oxford University Press, 1997). *The Mathematical Brain* falls into the second category: it is a skilful overview of the area for the non-specialist, with remarkable depth and breadth in many cases, but with occasional oversights that may frustrate the expert.

Butterworth's review of prehistory is particularly original and commendable. He convincingly pulls together little-known evidence from cave-paintings and bone-carvings to suggest that the dawn of arithmetic in stone-age populations dates back at least as far as 30,000 years. More puzzling, however, is the almost complete omission of brain-imaging evidence in the discussion of the neural bases of the number module. Although the modern tools of positron emission tomography, functional magnetic resonance imaging and electro- and magneto-encephalography have been applied only recently to mathematical cognition, a review of the available evidence would have been welcome, especially since it confirms the presence of numerical circuits in a localized brain region: the left inferior parietal region.

Specialists will be delighted, however, by Girelli and Butterworth's latest evidence on developmental dyscalculia, some of which is published here for the first time. If there is a genetic plan for a number module, then one might expect to find an occasional child who is born without it, either due to a genetic defect or to pre- or perinatal cerebral damage. Butterworth claims to have identified one such patient, Charles, who is "born blind to numerosities". Although Charles is now a very bright adult, with a university degree in psychology, he has experienced profound, lifelong difficulties in mathematics, to the point of still having to count on his fingers in order to solve single-digit addition problems.

Chronometric tests reveal at least two major impairments. First, Charles cannot "subitize": he cannot decide how many items are presented on a computer screen, even if there are only two or three, unless he painstakingly counts them one by one. Second, he has an abnormal intuition of number size, which is reflected in an inverse distance effect in a number-comparison task: whereas we normally take less time to decide which of two numbers is larger as the distance between them gets larger, Charles takes more time for more distant numbers, presumably because he is using a very indirect counting strategy.

Charles has not been subjected to brain imaging, but another case of developmental dyscalculia, recently scanned with the novel technology of magnetic resonance spectroscopy, shows a small, isolated area of damage exactly where number circuits are postulated to lie — the left inferior parietal cortex.

The finding that early focal brain damage can have such a permanent and restricted effect on mathematical competence is perhaps the best evidence to date in favour of the number-module hypothesis. Such evidence imposes strong limits on brain plasticity and clearly speaks against purely constructivist theories that view mathematical competence as the result of a general learning device.

In the end, I suspect that Butterworth's hypothesis of a direct link between genes, number circuits and higher mathematical competence may be too simple. Still, the cogent arguments of *The Mathematical Brain* should be required reading for anyone interested in the modularity of higher cognitive functions. ■

Stanislas Dehaene is at Unité INSERM 334, Service Hospitalier Frédéric Joliot, 4 Place du Général Leclerc, 91401 Orsay cedex, France.

Biochemistry: a biography

Proteins, Enzymes, Genes: The Interplay of Chemistry and Biology
by Joseph S. Fruton
Yale University Press: 1999. $45, £30

Charles Tanford and Jacqueline Reynolds

F. Gowland Hopkins, Cambridge University's first professor of biochemistry and recipient of a Nobel prize for his work on vitamins, said in a lecture delivered in 1927: "Biology and chemistry, though in their infancy both foster-children of medicine and passing their childhood in company, have long occupied domains which, though never really far apart, have sometimes