processing that might have been thought to be more properly the province of psychologists.

On the success of the enterprise, however, the jury is still out. As Weinberg comments in Vol. I, ". . . a theory that characterizes what we know about our language in such a way that this knowledge could never efficiently be put to use would not seem to be a very promising psychological candidate". This cautionary note, written in the context of whether chomskyan grammars could be efficiently parsed (that is, processed) by a machine, might be applied throughout these volumes. It is one thing to enunciate general constraints on language learning, it is quite another to incorporate these constraints into a realistic psychological model. But as a way of understanding complex phenomena, it still beats dressing up in feathers and jumping off a cliff. □

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On fibreglass and fishes

R. McNeill Alexander

Axis and Circumference: The Cylindrical Shape of Plants and Animals. By Stephen A. Wainwright. *Harvard University Press: 1988. Pp. 132. $22.95, £18.50.*
The Science of Structures and Materials. By J.E. Gordon. *W.H. Freeman: 1988. Pp. 217. $32.95, £14.95.*

PROFESSOR Wainwright is a biologist who thinks like an engineer and Professor Gordon is an engineer with an interest in biology. Wainwright studies the design of animals and plants, thinking of them as structures built of appropriate materials. Gordon studies the design of structural materials, both man-made and natural. Both have written books that will make their ideas accessible to anyone who studied science at school. Wainwright's book should also be required reading for students and research workers in animal and plant morphology.

Wainwright has been remarkably influential as a teacher as well as in research. Most North American research workers in comparative biomechanics seem at some stage to have been his students, and to have been infected by his enthusiasm and mesmerized by his luxuriant bow ties. The theme of his new, short book is that the cylinder is the basic shape of multicellular life. Worms and eels are cylinders with pointed ends; rose bushes and monkeys are branched structures built of several cylinders each. A few basic principles associated with cylindrical shape illuminate most animal and plant structures.

To make a cylinder strong but flexible you should put its skeletal material along the axis, as in the roots of plants and the backs of vertebrate animals. To make it resist bending you should put the skeletal material at the circumference, as in bamboo stems and crab legs. To enable it to bend without kinking or twisting you should wrap it in a criss-cross array of helical fibres, like the fibres in the cuticle of some nematode worms and under the blubber of whales. Joints and suitably arranged muscles make mechanisms built of rigid cylinders, such as human arms, capable of a wide range of movements. Muscles in flexible cylinders such as octopus arms can also produce a wide range of movements, free of the constraint of localized joints.

Occasionally, Wainwright's stimulating book seems just a little *too* easy to read. Not everyone who reads that "bending and twisting are complex and thus potentially dangerous deformations" will stop to wonder what, if anything, that means. A convincing-looking graph shows that a long, thin, cylindrical animal can make itself much longer by contracting its diameter slightly, but Wainwright fails to point out that a given percentage reduction in diameter always gives the same percentage increase in length, however stout or slender the cylinder.

Gordon took his first degree in naval architecture, and during the Second World War worked on materials for aircraft construction. Subsequently he became a professor at Reading University, where he associated with biologists as well as with engineers. He played a distinguished part in the development of fracture mechanics but is also the author of the funniest and most enlightening popular books on mechanics, *The New Science of Strong Materials, or Why You Don't Fall Through the Floor* (1968) and *Structures* (1978). The main theme in this new book, as in the older ones, is that we all need to know about fracture mechanics, whether we be engineers, biologists, orthopaedic surgeons or even military historians.

The ancient Greeks may have won the Battle of Marathon because their annealed bronze armour was soft enough to be dented by the Persian arrows: it absorbed the arrows' kinetic energy and stopped them without cracking. Similarly, antler is more flexible than ordinary bone (it contains a smaller proportion of mineral salts) and so is better able to absorb the impacts of fighting stags. The same property made it excellent for making prehistoric pickaxes.

Antler, wood, fibreglass and the carbon-epoxy materials used in aircraft construction are composites, built of strong fibres embedded in a relatively weak matrix. The strength of the material is paradoxically dependent on the weakness of the matrix, which fails in front of the tip of a crack and dissipates the stress concentration that would enable the crack to spread. Roofs, bridges, aeroplanes and many other structures are best made as light as is safe. The weight of a structure can often be reduced by designing it so that as many as possible of its members are in tension, because compression

Putting on the brakes — for a bird, large changes in geometry are needed to produce the forces required in manoeuvres such as landing: wings arched, legs outspread and tail bent forward and splayed to create drag while maintaining lift at low speed. Aircraft command much higher power/weight ratios and generally do not need such techniques, but aircraft like Concorde or the swing-wing fighter do display considerable changes in form. The picture is taken from a further book on structures, Invention and Evolution: Design in Nature and Engineering *by M. J. French, recently published by Cambridge University Press, price hbk £35, $59.50; pbk £12.50, $19.95.*