Valley of Scotland, which overlies sedimentary rocks, and the wild highlands to the north, betraying the presence of tougher metamorphic rocks beneath. But Fortey tells us, too, about the plants that flourish on the nutrient-poor moors of the highlands: for example, the berries of the heath family (Ericaceae), which spark a paragraph's digression about the problem of obtaining vitamin C in high-latitude regions. Other highland plants prompt reflections on the survival of primitive forms in harsh conditions (the clubmosses on today's moors trace their heritage back to Carboniferous coal swamps) and the stranding of Arctic flora on British peaks as the glaciers retreated.

From flora, on to fauna: as the heather follows the geology, so does the grouse. Why are brown trout found in the streams of both Derbyshire and Hampshire? Because both regions are underlain by limestone — respectively, Carboniferous and Cretaceous (the famous Chalk). Nor are humans impervious to the influence of the hidden landscape. Fortey goes beyond the obvious examples of agriculture (dictated by the fertility of the soil, itself controlled by the bedrock) and mining, to argue that much of today's human geography still reflects the geological imperative. The vales flooded by Permian and Triassic rocks are "natural corridors for traffic and trade"; hence one finds canals along them, and also ancient towns. The wool towns of western and middle England grew up near the outcrop of the Fuller's Earth — a Jurassic deposit rich in the clay mineral montmorillonite, which can be used to clean wool of its natural grease. The modern chemical company ICI owes its location, argues Fortey, to the outcrop of Permo-Triassic salt.

To appreciate many of Fortey's examples, one needs to be fairly familiar with British geography. Instead of having the geological map of Britain and Ireland reproduced twice, could we not have had a topographic map, to aid readers who would not otherwise know what it means for a rock formation to extend "from Nottingham to Sunderland, with its widest outcrop at the coast north of Hartlepool"? More generally, one often gets the feeling that Fortey is writing for a British audience — which is a shame, as this is emphatically not just a book about the geology of the British Isles; it is about how an appreciation of geology and its hidden connections can enrich one's experience of life in exactly the same way as can an understanding of art or music. To quote one of Fortey's more whimsical examples, does it not deepen the enjoyment of a whisky and mineral water to notice that although one ingredient is Scottish and the other English, they both originate in rocks of the Precambrian era?

But the ability to recognize harmony necessarily brings with it a sensitivity to

discord. The flip side of the pleasure provided by vernacular architecture — buildings made from local stone, "at ease with [their] geological foundations" — is the pain brought on when the connections are ignored. In this regard, Fortey is perhaps an extreme geological aesthete: he rails, not just against the brightly coloured petrol station which we might all recognize as a modern synthetic abomination (although he adds that it does not even have the modesty to clothe itself in lichens, as the local stone does), but against the embarrassment of houses made of Jurassic Bath stone sitting on the Cretaceous chalklands. One feels for him, as for the person whose hyper-perfect pitch ruins the enjoyment of an average concert; but even those of us with more normal sensibilities will acknowledge the loss entailed in the march of uniform brick and slate across what was a richly varied landscape.

Fortey's stated aim is to "inspire a way of looking at the landscape". Read this book and you will never see the world around you in quite the same way again. □

Laura Garwin is Physical Sciences Editor of Nature.

Technopolis

Henry Petroski

A Scientist in the City. By James Trefil. Doubleday: 1994. Pp. 266. \$23.95.

AMONG the fundamental differences between scientists and engineers are their generally divergent objectives. The purest scientists observe and study the given world only to understand and explain it and its phenomena; the purest engineers want to manipulate the parts and processes of the given and found world into artefacts of benefit to mankind. Scientists analyse; engineers synthesize. The products of science thus tend to be words and theories; the products of engineers are plans and things.

In his latest book, the scientist-writer James Trefil turns his analytical eye to the quintessential products of synthesis — cities and their artefacts. As with much science, his musings begin in wonder, specifically atop the Sears Tower looking down at Chicago, and he progresses from wondering about what problems had to be solved to build the world's tallest building to wondering "what else in the city depended in a similar way on our basic understanding of science and nature".

Allowing Trefil the simplistic conventional wisdom that engineering and technological advances are little more than applied science, the premise of his book is an excellent one, and even an engineer

might sympathize with the popular goal of wanting the reader to see modern cities as "products of a series of discoveries of the physical universe". Trefil proposes in his introduction to accomplish this objective by looking at three discoveries: "the ability to manipulate atoms"; "the ability to unlock stored energy"; and "the ability to store and transmit information electrically". But the reader might be advised to keep in mind that each of these discoveries or accomplishments is in fact a feat of engineering that may or may not involve science in the usual sense. Indeed, manipulating atoms over fire, perhaps one of the essential hallmarks of civilization, required neither formal science nor engineering, although the craft may have been honed by the rudiments of their methods.

Despite oversimplifications of fundamentals, which are understandably made in the interest of getting on with the story, the book is a good read. Trefil tells interesting tales about the development of such materials as the glass and steel that go into modern skyscrapers, and he explains well the problems associated with moving things such as people, water and waste in very tall buildings. The first half deals with the city of today, and with Trefil's personal encounters among the systems of several specific cities; the second half of the book deals with the city of the future. Amid discussions of the implications of life among very tall buildings and the nature of suburbs, Trefil covers a lot of ground, sometimes as fast as the Maglev trains that he describes as redefining the distances commuters of the future will tolerate, in the rare time they might have to leave the information highway at home and travel to the office.

In the end, the success of science and engineering, and of books on them, rests in the details. Trefil assures the reader that "engineers, you know, are a gloomy lot, always dwelling on what can go wrong with their systems", but he neglects to remind us that by "dwelling on what can go wrong", engineers are striving to get it right so their products can be relied on by those who are not engineers. Who wants engineers to be so sanguine about an elevated walkway that they leave the design details to the construction workers?

Although Trefil is not an engineer, he might have been a bit more critical of some of the details on which his own construction rests. For example, what he says engineers call "shear loads" they might hardly recognize. Steel reinforcing rods do not provide strength directly against shear, as Trefil states on page 36, but against tension, in which concrete is weak. The illustrations in the book can be equally wrong. The figure purporting to show the "flow of force on a lintel", for example, has the lintel between the posts rather than resting on top of them. The

caption to a figure comparing Frank Lloyd Wright's mile-high skyscraper (which was never built) to more familiar structures states that they are drawn to scale, and yet they are not. Such a neglect of detail jeopardizes an otherwise intriguing book, for the gloomy engineer has naturally to wonder about the details of those parts for which he must rely on the scientist. □

Henry Petroski is in the Department of Civil and Environmental Engineering, Duke University, Box 90287, Durham, North Carolina 27708-0287, USA.

Behind the birdies

Stephen Salter

The Physics of Golf. By Theodore P. Jorgensen. *American Institute of Physics/Oxford University Press: 1993.* Pp. 155. \$35, £27.50.

It was on grounds of national security that the Scottish Parliament introduced successive acts (1451, 1457 and 1491) banning the game of golf. The unprofitable use of land, the loss of productive working hours, the stresses on family life, the danger of apoplexy and the reduced attendance at kirk were factors but it was the distraction from archery practice that was decisive.

With advances in military technology, golf has been decriminalized in Scotland and many other countries. Golfing equipment with a street value estimated at \$13 billion a year is now sold quite openly. Jorgensen's book on the physics of golf offers no suggestions for treatment of addicts but may help us to understand their problems.

His model of the golf swing consists of two stiff hinged rods, one representing the arms of the player and the other the club. He presents the algebra to predict the behaviour of this model in terms of five torques on the golfer's arms. He supports the predictions with stroboscopic photographs of patches of reflective tape stuck to the club and to points on the body of the golfer. The observations are in good agreement despite the simplicity of the rigid two-rod model.

Many of the results are intriguing. For example, a marker on the head of a golfer will trace a curve that is as unique as his signature — a more enjoyable method of security identification than fingerprinting. In a good golf stroke the velocity of the golfer's hands decreases on contact with the ball, while that of the club head continues to increase. Similarly, a bull

whip makes a supersonic crack when most of it is static and all the kinetic energy has been transferred to the very tip.

Did you know that bull whips should have lead weights near the handle? Did you know that you can break the shaft of a club by not allowing your wrists to rotate? Did you know that a perfect ball would leave the tee at twice the speed of the club head? Good players achieve a ratio of 1.4 which suggests that there may still be room for design improvement.

Jorgensen calculates the instantaneous power delivery of human muscle and says that the amount of muscle needed (32 pounds or 15 kilograms) is far more than is available in arms and shoulders (he suggests that a visit to the butcher will confirm this). He argues that other muscles in the legs and back must be in use, passing energy through the arms.

The book contains enough experimental detail to allow readers to replicate results. An interesting example is the work of Peter Guthrie Tait in 1887 on ball spin. Working without electronic instruments or fast photography, he measured spin by attaching a flat ribbon to a golf ball and driving it into a nearby bank of thick clay. By counting the twists of ribbon, Tait calculated that the rate of spin was as much as 120 turns per second or 7,200 revolutions per minute, depending on the angle of the club face. Many people did not believe him.

despite the different weights of their heads and the fact that golfers like clubs of different lengths in their set. The method involves placing small weights at two places along the club shaft so that the total weight, the first moment and the second moment are the same. Small changes of weight, of the order of 1 gram, are involved. Good golfers seem to like the results.

A whole chapter is devoted to the laws of probability and their relationship to golf. The author collects data from the score cards of a pair of players over 20 games and calculates the probability of various scores. The Gaussian distribution strikes yet again. Twenty games — about 1,500 strokes — seem to be plenty to give the familiar smooth curves. Golf authorities have not so far devised a way of awarding non-integral handicaps. Jorgensen shows that this will prevent better players retaining an advantage.

Jorgensen writes for a wide readership ranging from nongolfing fellow physicists, who may find some of the verbal explanations rather laboured, to nonscientific golfers, who may wince at the algebra. He spans the gap with appendices for the heavier maths; readers should be tolerant.

Relaxed sportsmen in the United States will be less irritated than pedantic academics in Europe by the promiscuous mixture of physical units. Many results are given in inches, feet and yards with ounces

and pounds for force. When Jorgensen goes metric he uses grams and centimetres. Club makers use an extraordinary measure, the Lorythmic swing-weight scale, in which ounce-inches of moment about a point 12 inches from the grip end are divided into letter numbers in bands of 20 ounce-inches, which are then subdivided into numbered bands of 2 ounce-inches. We can be grateful to Jorgensen for a clear explanation.

It was rather mean of the publishers not to include one of Harold Edgerton's splendid flash photographs of a golf ball flattened to half its diameter: the peak force between club and ball can exceed 3,000 pounds — more than the weight of a family car. There is only one page of references and a three-page index, but this will not detract from one's enjoyment of the book.

Golfing addicts now need a psychologist to explain the ecstasy of hitting a golf ball exactly right. I can testify to the addictive power, managing such a hit once in 1958 and again in 1987. No wonder the Scottish Parliament needed more than one act. □

Stephen Salter is in the Department of Mechanical Engineering, University of Edinburgh, Edinburgh EH9 3JL, UK.

Swinging both ways — woman golfer from *La Vie Parisienne*, 1908.

The rotation is produced in the fraction of a millisecond in which the ball is in contact with the club face. It has a profound influence on the flight of the ball because of the Magnus effect. The author explains how it can induce a lift force nearly as large as the gravitational weight of the ball.

Jorgensen explains how to match a set of clubs so that they all feel the same