expected from studies of other Western subjects. His travels to these regions and his discoveries are presented as engaging personal experiences. He ends his book with a particularly notable example of the remarkable clinical experiences of Terry Shintani and colleagues, who have studied the food sensitivities now suffered by indigenous Hawaiians as they adopt a modern Western diet.

The story told by Nabhan is thought-provoking. He implies that each of us, as individuals, should consider our food choices and their health effects with reference to our own evolutionary past. However reasonable this argument seems, it leaves unanswered the critical question of how such information can be used to create contemporary dietary advice for the public. Most people now are a heterogeneous mixture of genes and food habits that will be virtually impossible to untangle in a way that can tell us what we should be eating to be healthy. Even if we knew the evolutionary pedigree of our contemporary genes — which is most improbable — we would be hard put to match our genetic predispositions with the specific foods likely to make us most healthy. I dread to think what the marketplace will make of this account.

In decrying the one-size-fits-all diet proposal promoted by some dietary advocates, Nabhan seems to ignore the remarkable nutritional range and food choices that exist within such supposedly monolithic diets. For example, the recommended low-fat, whole-food, plant-based diet neither connotes an unvarying diet nor implies exactly the same health benefits for all consumers. It allows for, and even encourages, the consumption of a wide variety of such foods. But the diversity for different regions and different groups of people can still be used to generate most of the same health benefits. This is the beauty of the work of Shintani and his colleagues, who have produced remarkable health benefits when obese and diabetic native Hawaiians are re-introduced to their native whole-plant-based foods, which are low in fat and high in fibre and antioxidants. In a similar way, a range of different plant-based foods can be used to control or even reverse a variety of serious diseases.

It is remarkable that meaningful genetic adaptation can occur in a few thousand years or so, but even more so that genetic-like adaptations can occur within only one or two lifetimes. Dietary experiences before or shortly after birth, either direct or maternal, can imprint substantial biochemical and morphological changes that become stabilized well into adulthood as if they were genetic — yet they are more likely to be post-transcriptional or post-translational. Such is the nature of dietary adaptation, a process that is continually at work, short term and long term, minimizing harm and making the most of what food and other resources are available.

Despite these minor criticisms, the book is well worth reading, for it should stimulate an important debate about what constitutes dietary adaptations and sensitivities. ■

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The sincerest form of flattery

Imitation of Life: How Biology is Inspiring Computing
by Nancy Forbes
MIT Press: 2004. 176 pp. $25.95, £16.95

John Doyle and Marie Csete

Generations of engineers have recognized that, in many respects, biology does it better. *Imitation of Life* is a whirlwind history, richer even than its subtitle suggests, through various computational disciplines inspired by biology. This is an ambitious undertaking for such a short book but, although it ignores some important unifying principles, its brevity is also a virtue. The inspirations from biology are scattered throughout the book, and their collective impact is felt best when the book is digested whole, at one sitting. The early chapters on biology as a metaphor are the least satisfying, and any reader who stops there may never return for the genuine delights that follow.

Some historians argue that the inspiration provided by avian feathers and flapping may have delayed heavier-than-air flight for centuries. Critics would argue that artificial neural nets, genetic algorithms, cellular automata and artificial life, which are covered in the first four chapters, are the modern equivalents of flapping, whereas advocates see them as mature fields no longer in need of review. Nancy Forbes is generous about their successes, but does little to resolve the issue. Only later are there brief discussions of hierarchy, modularity, layers of control, and system architecture — key concepts in computing that could help to inform a more thorough analysis.

In contrast to the earlier sections, which use biology as a metaphor, the chapters on DNA computing and biomolecular self-assembly describe the direct use of biological chemistry or materials to create technological artefacts that have little or nothing to do with biology. Forbes is clearly more interested in these topics, and this enthusiasm may well spread to readers; the section on the intriguing computational power in the organization of DNA is particularly well presented. These chapters start to make it clear that understanding biological principles in some depth is an essential part of profitable imitation. Making DNA computing work requires a firm grasp of the principles and careful design, but now anyone can download cellular automata or genetic algorithm software and run laptop artificial-life experiments.

The chapters on amorphous computing, computer immune systems and biologically inspired hardware further underscore the idea that, as biology is better understood, inspiration can proceed more from mimicry than metaphor, and contribute more directly to solving difficult computational tasks. What makes this work (and these chapters) more compelling is the fact that engineers in these fields have crossed disciplinary lines to gather a deep and practical understanding of biology and biological experimentation. The recent explosion in our detailed knowledge of biology, and the glimpses this provides of its organizing principles, has considerably enriched biologicaly inspired computing.

The final chapter reverses direction and

looks at biology through the lens of computer science and electrical engineering. This is conceptually the deepest chapter but its brevity limits it to a few well-chosen examples. The technologies of any age have always provided metaphors for biology — from myths about our origin involving dust and clay to the industrial revolution's hydraulic and, later, electromagnetic imagery, from telegraphs to telephones and finally to computers. The book contains almost no explicit discussion of complexity, and this omission is particularly noticeable here. Much of computer science is about organizing complexity, from 'very large-scale integrated' circuit design to object-oriented programming and the layered protocols of the Internet.

The history of flight is again instructive. By the nineteenth century, engineers had realized that lift, drag and propulsion were the key fundamental mechanisms, and toy gliders became commonplace. Yet only with the Wright brothers' insight that active control was needed for steering and compensation for uncertainties did flying literally take off. By the 1940s, unpiloted aircraft had demonstrated fully automatic transatlantic flight and landing, and some engineers now argue that flight would generally be safer without pilots.

Similarly, the vast majority of computers now are 'embedded', with automated sensing, control and actuation, all entirely hidden during normal operation. Computer control systems such as these represent both the main use of computers and the main source of complexity in technological systems, but are barely mentioned either in this book or elsewhere. This is a pity, as they are the points of greatest contact between engineering and biology. Biologists would have benefited from a discussion of sensing and adaptation in computation and networking, such as Internet routing and congestion control, because sensing and adaptation are widespread in biology, for example in the immune system. Perhaps biologically inspired computing is not yet at a 'Wright brothers' stage, with many fundamental mechanisms just emerging, old superficial metaphors being set aside, and systems-level integrating concepts remaining murky. Hopefully, the Wright brothers of biologically inspired computing are among the many fascinating characters described by Forbes, and their subjects will take off as promised.

This book is easily accessible but is probably most suited to, and beneficial for, biologists, as a clearly written, non-technical primer describing activities on the other side of campus. Biologists will have to ignore some unfortunate simple errors (such as neurons called axons, AIDS as an autoimmune disease and vaccines made from weakened antigens) but can easily read around them. Nonetheless, this text helps to bridge a daunting technical language barrier and should facilitate further dialogue between biologists and computer scientists. ■

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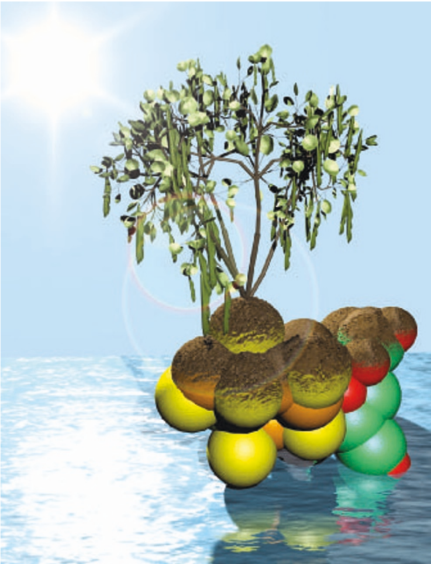

The roots of nitrogen fixation

The World's Greatest Fix: A History of Nitrogen in Agriculture
by G. J. Leigh
Oxford University Press: 2004. 254 pp. £20, $29.95

Vaclav Smil

The discovery by Fritz Haber of a method for fixing ammonia from its elements led to the development of the modern nitrogen-fertilizer industry. The growing applications of nitrogen compounds in agriculture have had enormous demographic, economic and environmental consequences. Most histories of nitrogen fixation focus on this part of the story, but in *The World's Greatest Fix*, G. J. Leigh provides a more evenly distributed account. Nearly two-thirds of Leigh's text is devoted to general considerations of nitrogen's chemistry and agronomy, and of technical developments before Haber's discovery.

The book begins with a brief introduction to nitrogen fixation and its importance for agriculture, before tracing the development of agronomic practices in pre-Colombian America (by the Aztecs and Mayas), dynastic China and the Roman Empire, with particular attention to classic agricultural accounts (and the value of manure) by Cato the Censor, Columella, Pliny the Elder and Varro. Next, the story advances to the modern era, focusing on English farming from Roman times to the beginning of scientific agriculture in the seventeenth century, before moving on to the trade in guano (bird droppings are a rich source of nitrogen) and Chilean nitrates (originally Bolivian and Peruvian) — England was the leading importer of these sources of nitrogen. Leigh then takes us into the laboratory, dealing with the alchemy of nitre and the early chemistry of nitrogen (from Paracelsus to Lavoisier and Chaptal), the birth of agricultural chemistry (thanks to Davy, von Liebig and Boussingault) and the discovery (by Hellriegel and Wilfarth) that microorganisms and some plants can fix their own nitrogen.

Leigh then describes the evolution of the first commercial methods invented to fix nitrogen. The Norwegian arc process, which combines N_2 and O_2 in an electric arc furnace and uses the resulting nitric oxide to produce HNO_3, was made possible by inexpensive hydroelectricity. The synthesis of cyanamide, by reacting CaC_2 with N_2, also fixed nitrogen but was energy-intensive. Next come Haber's experiments, beginning in 1903, and the quest, led by Carl Bosch, to commercialize them, beginning at the BASF plant in Ludwigshafen, Germany, in 1909. Here I found the only factual errors worth noting: the German chemist who formulated the effective catalysts needed to run the ammonia synthesis was Alwin (not Alois) Mittasch. This work also led to the synthesis of methyl alcohol and the hydrogenation of coal. And Mittasch did not collaborate with Haber in 1903 (at the time he was Ostwald's assistant in Leipzig); he joined BASF in 1904, working under Bosch.

The penultimate chapter explores the continuing mystery of biological fixation, the author's main area of research interest — he spent most of his professional life at the Unit of Nitrogen Fixation, which was set up in the mid-1960s at the University of Sussex. He describes the discovery of nitrogenases — the enzymes that fix nitrogen in both free-living and symbiotic bacteria — and their modes of action; he discusses the structures made up of iron, molybdenum and sulphur that are at the heart of these remarkable molecules; and he reviews the unsolved puzzles regarding their active sites.

In closing, Leigh reviews the scale and effects of nitrogen-fertilizer use, focusing on aquatic eutrophication — in which excessive nitrogen promotes algal growth and the subsequent depletion of oxygen — and nitrates and human health. The health effects of nitrates are frequently exaggerated, but eutrophication, which Leigh treats rather lightly, still does not get enough attention, given its severity and increasing occurrence. There is also now considerable eutrophication of terrestrial ecosystems.

I always like unusual tit-bits, asides and images, and Leigh's book has its share of them. Among my favourites is a reference to Humphrey Davy's discussion of various